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AERONAUTICAL FACILITIES CATALOGUE

Volume 2

# *AIRBREATHING PROPULSION AND FLIGHT SIMULATORS*

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# *AIRBREATHING PROPULSION AND FLIGHT SIMULATORS*

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NASA Scientific and Technical Information Branch 1985
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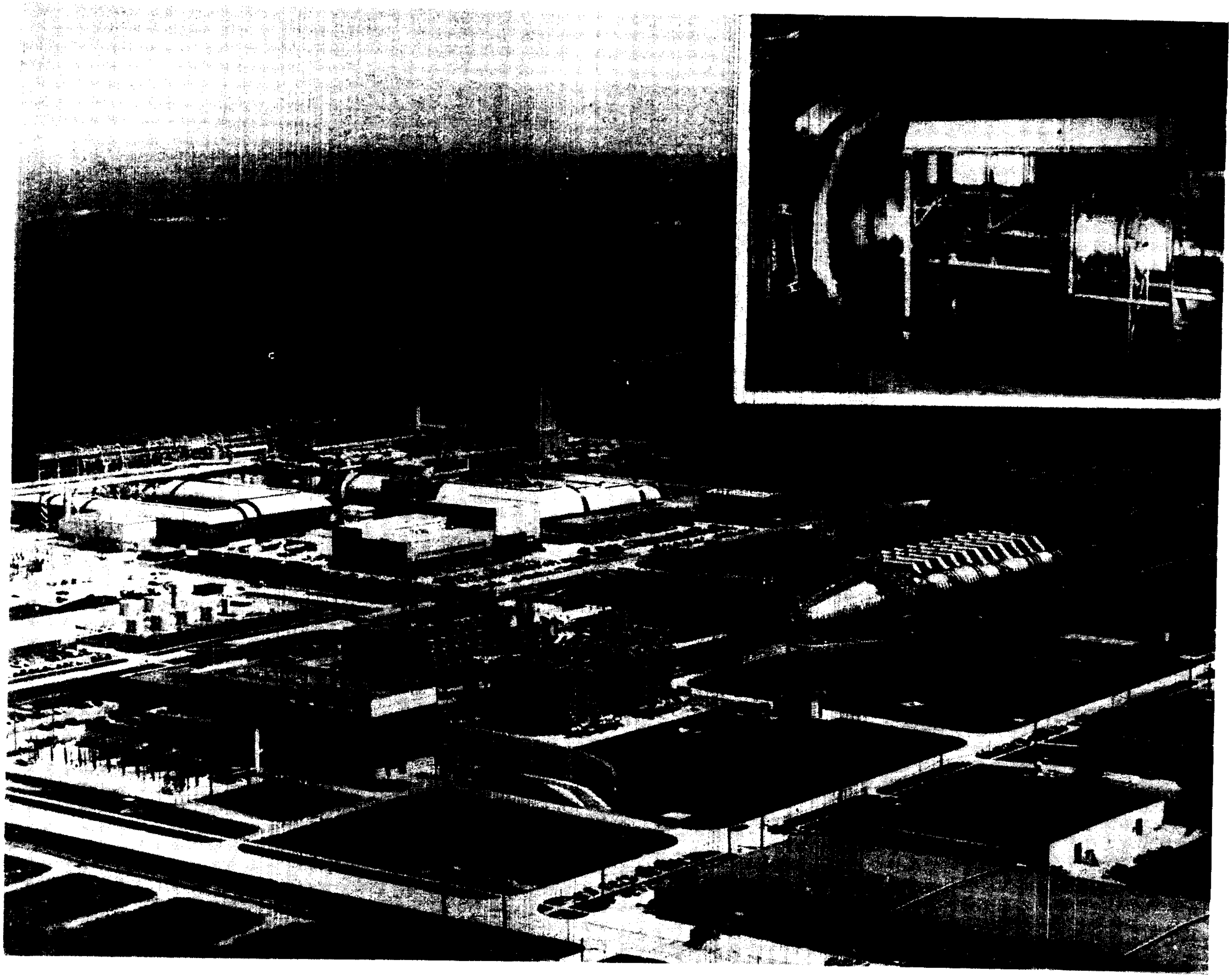

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# ACKNOWLEDGMENTS

The editors wish to thank all of the contributors in the various U.S. Government laboratories, industry, and academia for their cooperation and assistance in providing the up-to-date technical information, schematics, and performance charts shown in these volumes. We are grateful to the European nations and Japan who responded to this survey and helped make this a more complete catalogue.

We wish to recognize the outstanding effort and cooperation given to us by the National Aeronautics and Space Administration and Department of Defense scientists and engineers who had the difficult task of reviewing, verifying, and analyzing the information in this catalogue. Their knowledge and experience in their fields made it possible to provide the assessment of comparable facilities as a key feature.

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# PREFACE

This catalogue updates and supplements previous surveys conducted on Aeronautical facilities, particularly Wind Tunnels. It is more extensive than previous efforts in that it also includes Flight Simulators and Propulsion Component facilities in addition to the wind tunnel and engine test stand data provided by the other surveys. Moreover, foreign (non-U.S.) facilities information, generally missing from most of the previous compilations, has also been included. Due to its broad coverage, the information in this catalogue has been divided into two volumes: Volume I for Wind Tunnels, and Volume II for Airbreathing Propulsion and Flight Simulation facilities.

The National Aeronautics and Space Administration (NASA) undertook this survey primarily to form a current data base from which to assess its own capabilities and that of the United States in Aeronautical Research and Development, particularly in relation to that of the Western World. This assessment is a continuing one aimed at underscoring where the principal facility strengths and weaknesses exist and where future emphasis must be placed to ensure continued excellence in the research, development, and testing of future aeronautical vehicles and systems.

A secondary objective of this survey was to create a comprehensive guide for users and operators of aeronautical facilities. It is the latter objective that has actually driven the extensive effort behind this catalogue in an attempt to present the available information in the most accurate, understandable, and useful manner. For this reason, several cross-references, tables, and analyses have been included in these two volumes.

All the information contained in these volumes has been provided or verified by the facility owners or operators. The data-gathering process was slow and lengthy to ensure accuracy and thoroughness, although the ultimate product can reflect no more than the effort put in it by the individual contributors. First, a suitable format for presenting the data was designed. The objective was to present the catalogue user with as much "quick-glance" information as possible on the principal features of a facility so as to make a search task simpler. The next step involved a literature search of all previous surveys and reports to form a data base. This data base was transcribed into the new format and sent to the appropriate facility owners/operators for editing and verification. Owners/operators were given the option to either include or exclude their facilities, including currently inactive or standby facilities. However, permanently deactivated facilities have not been listed. Where particular facilities provided by an owner/operator have been omitted, it is very likely that they failed to meet the criteria established for each category of facility.

A special feature of this catalogue is the identification of comparable facilities that may serve as alternatives to a user's research or test needs. A select group of experts from NASA and the Department of Defense in each facility category reviewed the available data for each facility and created the various tables and guides provided in the appropriate locations throughout the catalogue, along with detailed discussions of the criteria used in their evaluations.

Of particular interest in this survey was the inclusion of the major facility capabilities in the rest of the Western World and Japan. Laboratories and government organizations in each of the countries for which some information was already available were solicited for contributions and/or for their verification of the available data. Good responses were received for wind tunnels, and a fair response was received for engine research and test facilities. However, little or no response was received for the flight simulation or propulsion component facilities. The foreign countries covered by this catalogue include Canada, France, the Federal Republic of Germany, Japan, the Netherlands, and the United Kingdom. Although other aeronautical facilities may exist in other countries, either they were not considered major or no information was solicited from those countries.

The editors regret any undetected errors of omission or commission and welcome any corrections, additions, comments, or suggestions for improving future versions of this catalogue.

# CATALOGUE OUTLINE AND STRUCTURE

The complete *Catalogue of Aeronautical Facilities* is composed of two volumes:

Volume I – Wind Tunnels

Volume II – Airbreathing Propulsion and Flight Simulators

The two volumes are similarly structured and can stand alone or as a set. Each is divided into major sections that cover a specific class of facilities: Wind Tunnels, Engine Research Facilities, Propulsion Component Facilities, and Simulators. Within each major section, the facilities are grouped according to categories or types such as speed regimes for the wind tunnels, turbine, compressors, and combustors for engine component facilities, etc. Additional subgroupings are also provided as appropriate.

The structure of each volume contains the same general features:

- General Table of Contents
- Introduction for Each Major Section
- Explanation of Format and Content of Data Sheets
- Cross-Index of Facilities by Installation
- Individual Sections by Facility Types
  - Comparable Facility Listings
  - Index and Specific Table of Contents
  - Individual Data Sheets
- List of Installation Addresses
- Glossary

## INTRODUCTION

An introduction to each major section presents the overall content of the section, introduces the specific facility groups and subgroups therein, defines the selection criteria used for the inclusion of individual facilities in the catalogue, defines the technical parameters and the format in which those are presented, and provides some performance and statistical comparison charts for the various facility groups.

## CROSS-INDEX

Since facilities in this catalogue are listed by type, a cross-index by installation is included for each major section. Because it contains the most pertinent parameters and characteristics of each facility, this index also serves as a quick-reference guide to facility capabilities.

## INDIVIDUAL SECTIONS

Facilities showing common basic characteristics, such as transonic tunnels or turbofan engine facilities, are grouped and presented in separate sections. Each section contains an overview of the group's overall capabilities, an assessment and guide of comparable facilities, an index and table of contents of the facilities listed therein, and the individual facility data sheets.

## FACILITY DATA SHEETS

The heart of the catalogue is the detailed information that has been gathered on individual facilities and compiled in the logical groups indicated above. Each facility is presented in a two-page format that contains graphical as well as tabular and narrative information. The main page contains a summary or "quick-glance" chart of the most pertinent information concerning that facility, followed by narrative statements elaborating on the technical capabilities and research or test programs associated with it. The identification in each chart of related or comparable facilities that may be used as alternatives for similar research or test purposes is also included, as is a contact point for additional information. The opposite or facing page shows schematic diagrams of the facility's layout, plus pertinent performance charts if the facility owners/operators have made them available.

## LIST OF INSTALLATION ADDRESSES

Supplementary information on the location of each laboratory or installation referenced in this catalogue is provided in the back of each volume in alphabetical order.

## GLOSSARY

Definitions of abbreviations, acronyms, and the less common terminology used in this catalogue are also provided in the back of each volume.

# CONTENTS

# INTRODUCTION
# VOLUME 2

Whereas Volume 1 of this catalogue is dedicated to Wind Tunnels, Volume 2 contains the other two major categories of aeronautical facilities:

- Airbreathing Propulsion
- Flight Simulators

These are further divided into the following subcategories:

- Airbreathing Propulsion
  - Propulsion Wind Tunnels
  - Engine Altitude Test Facilities
  - Propulsion Component Facilities: Turbines, Compressors, Combustors
- Flight Simulators
  - Airborne Simulators
  - High-Performance Aircraft Simulators
  - Vehicle-Specific Flight Decks
  - Generic Flight Decks

As was done for wind tunnels, the survey of the airbreathing propulsion and flight simulation facilities covered U.S. Government laboratories, industry, and foreign installations. The response was good from U.S. sources, but only marginal to poor from other countries; particularly for propulsion component and simulation facilities, where the response was negligible. Nevertheless, it is estimated that the predominance of the propulsion facilities in the free world and of the flight simulators in the United States are included in this volume. The distribution of these facilities by owner/country and category is shown in Tables 1a and 1b.

For each facility category, individual criteria were chosen to determine which were to be included and which were not. The intent has been to present all the major facilities of research or test and development interest rather than of pedagogical or training value. The specific criteria are addressed in each section.

*Data Sheets*: Detailed information on each facility is presented by means of individual data sheets. These were designed to provide the user with the most salient features and capabilities in an easily readable and understandable format. The data box at the top of each sheet attempts to capture the most pertinent technical and operational information at a glance, while the narrative portion provides additional insights on the facility's potential uses and current programs. For purposes of uniformity, simplicity, and ease of reference, a single general format was designed for the entire catalogue. However, considering the broad spectrum of facilities contained herein and wide variation in the technical parameters pertinent to each, the specific information contained in the data boxes was tailored to each facility category or subcategory. Detailed descriptions of these individual formats are provided in each section.

*Comparable Facilities*: An attempt has been made in this catalogue to provide the user with a directory of facilities that are comparable in capability and use. The intent is to give the user a sense of those facilities that could be used as alternatives in meeting their research or test requirements. Criteria employed in determining comparability (or interchangeability) are explained for each of the facility subcategories in their respective sections. Comparable facilities are identified for each facility in its individual data sheet. Moreover, where entire groups of comparable facilities have been identified, these are listed by groups and designated by a number or letter code that is referenced in the individual data sheets. The latter are then presented consecutively in their corresponding groups.

*Facility Indices*: For ease of reference, several indices have been included in this catalogue. A general cross-index by installation is provided for each of the major facility categories (airbreathing propulsion and simulators). In addition, individual indices for each of the facility subcategories have been included at the beginning of each of their respective sections, followed by the comparable facility listings indicated above (where applicable) and their respective data sheets.

*Schematic and Performance Charts*: As was done for the Wind Tunnel volume, an attempt was made to have schematics/photographs and/or performance charts available for every facility, but it was not always possible (particularly for foreign facilities). Moreover, since the charts that have been included were generated by the individual owners/operators, no effort was made to make them uniform in either style or quality, although in some instances illegible or overly cluttered charts were redrawn or cleaned up. The principal reason for including these charts is to aid a prospective user in becoming more familiar with a facility than would be possible by just referencing the tabular and narrative information in the data sheets.

TABLE I-a

AIRBREATHING PROPULSION FACILITIES DISTRIBUTION

| | Wind Tunnels | Engine Facilities | Component Facilities | Total |
|---|---|---|---|---|
| UNITED STATES | 7 | 42 | 46 | 95 |
| NASA | 4 | 4 | 18 | 26 |
| DOD | 2 | 16 | 3 | 21 |
| Industry | 1 | 22 | 23 | 46 |
| Academia | – | – | 2 | 2 |
| FOREIGN | 3 | 15 | 7 | 25 |
| Canada | 1 | 1 | – | 2 |
| France | 1 | 4 | – | 5 |
| Germany | – | 1 | – | 1 |
| Japan | – | 1 | 7 | 8 |
| Netherlands | 1 | – | – | 1 |
| United Kingdom | – | 8 | – | 8 |
| TOTAL | 10 | 57 | 53 | 120 |

TABLE I-b

FLIGHT SIMULATION FACILITIES DISTRIBUTION

| | Airborne | High Perf. Aircraft | Vehicle Specific Flight Decks | Generic Flight Decks | Total |
|---|---|---|---|---|---|
| UNITED STATES | 3 | 4 | 9 | 24 | 40 |
| NASA | 1 | 1 | 2 | 8 | 22 |
| DOD | 2 | 1 | – | 5 | 8 |
| Industry | – | 2 | 7 | 11 | 20 |
| FOREIGN | 3 | 4 | 2 | 3 | 12 |
| Canada | 1 | – | – | – | 1 |
| France | – | 1 | – | – | 1 |
| Germany | 2 | 1 | – | 1 | 4 |
| Japan | – | 1 | 2 | 1 | 4 |
| Netherlands | – | – | – | 1 | 1 |
| United Kingdom | – | 1 | – | – | 1 |
| TOTAL | 6 | 8 | 11 | 27 | 52 |

# AIRBREATHING PROPULSION FACILITIES

# AIRBREATHING PROPULSION

The airbreathing propulsion facilities contained in this volume are listed in three main categories and are presented in the following order:

- Propulsion Wind Tunnels
- Altitude Engine Test Facilities
- Engine/Propulsion Component Facilities

These three categories cover the full range of the principal facilities required to develop and improve the aircraft engines used by both civil and military aviation.

The wind tunnels included in this volume are only those that permit real engine testing (engine burn) while the wind tunnel is in operation. Tunnels that provide only propulsion simulation capabilities through the use of compressed air-driven engine simulators (or similar techniques) have been omitted. They are covered with the other tunnels in the Wind Tunnel volume. The engine test facilities listed are only those providing altitude test capability. Sea level test stands are considered too numerous and do not provide the proper temperature and pressure conditions required for conducting full-range engine research and development. Facilities with both direct-connect and freejet capabilities are included. Of the engine/propulsion component facilities, only those providing R&D or testing capabilities for turbines, compressors, fans, and combustors are listed. Other facilities, rigs, or equipment dealing with fuels, lubricants, bearings, seals, and materials were considered too numerous and wide-spread for the purposes of this catalogue.

Since the parameters describing the salient capabilities of these facilities differ somewhat among the three categories, the data sheets for each category have been altered to reflect this difference. These are individually explained in their corresponding sections.

# AIRBREATHING PROPULSION CROSS-INDEX BY INSTALLATION

## PROPULSION WIND TUNNELS

| Page Number | Location and Facility Description | Test Section Size (ft) | Speed Range (Mach No.) | Dynamic Pres. ($lb/ft^2$) | Altitude Range (ft) | Temp Range (°F) |
|---|---|---|---|---|---|---|
| | U.S. NASA | | | | | |
| | Ames Research Center | | | | | |
| 30 | 40 x 80-ft | 40 x 80 x 80 L | 0 - 0.4 | 0 - 305 | Atmospheric | Ambient |
| 31 | 80 x 120-ft | 80 x 120 x 90 L | 0 - 0.15 | 0 - 305 | Atmospheric | Ambient |
| | Lewis Research Center | | | | | |
| 32 | 10 x 10-ft Supersonic Wind Tunnel | 10 x 10 x 40 L | 2.0 - 3.5 | 500 - 600 | 77 000 | 60; 690 |
| 33 | 8 x 6-ft Supersonic Wind Tunnel | 8 x 6 x 39 L | 0.36 - 2.0 | 200 - 1240 | Atmospheric | 60; 266 |
| | U.S. DOD | | | | | |
| | Arnold Engineering Development Center | | | | | |
| 34 | 16S | 15 x 16 x 40 L | 1.5 - 4.75 | 30 - 580 | 150 000 | 120; 620 |
| 35 | 16T | 16 x 16 x 40 L | 1.5 - 4.75 | 1.0 - 1000 | 90 000 | 120; 620 |
| | U.S. INDUSTRY | | | | | |
| | Boeing, Seattle | | | | | |
| 36 | 9 x 9-ft | 9 x 9 x 14.5 L | 0 - 0.33 | 0 - 127 | Atmospheric | Ambient |
| | CANADA | | | | | |
| | National Research Council | | | | | |
| 37 | 10 x 20-ft | 20 x 10 x 40 L | 0.007 - 0.184 | 0 - 50 | Atmospheric | Ambient |

## PROPULSION WIND TUNNELS

| Page Number | Location and Facility Description | Test Section Size (ft) | Speed Range (Mach No.) | Dynamic Pres. (lb/ft$^2$) | Altitude Range (ft) | Temp Range (°F) |
|---|---|---|---|---|---|---|
| | FRANCE | | | | | |
| | ONERA, Modane | | | | | |
| 38 | S1-MA | 20.5 x 22 x 46 L | 0.023 - 1.0 | 0 - 33 (knm$^2$) | 20 000 | 5; 122 |
| | NETHERLANDS | | | | | |
| | NLR and DFVLR | | | | | |
| | DNW | | | | | |
| 39 | 9.5 x 9.5 | 9.5 x 9.5 x 15 L (m) | 0 - 0.18 | 0 - 2.21 (knm$^2$) | Atmospheric | Ambient |
| 40 | 8 x 6 | 8 x 6 x 16 L (m) | 0 - 0.3 | 7.41 (knm$^2$) | Atmospheric | – |
| 41 | 6 x 6 | 6 x 6 (m) | 0 - 0.4 | 0 - 12.9 (knm$^2$) | Atmospheric | Ambient |

## ALTITUDE ENGINE TEST FACILITIES

| Page Number | Location and Facility Description | Mass Flow (lb/sec) | Pressure (psia) | Temperature (°F) | Altitude Range (ft) | Comments and Groupings |
|---|---|---|---|---|---|---|
| | U.S. NASA | | | | | |
| | Lewis Research Center | | | | | |
| 54 | PSL-3 | 480 | 60 | -50 - +600 | 5000 - 80 000 | Group 2 |
| 55 | PSL-4 | 480 | 60; 165 | -50; 600; +1200 | 5000 - 80 000 | Group 2 |
| | U.S. DOD | | | | | |
| | Arnold Engineering Development Center | | | | | |
| 56 | T-1 | 450; 800 | 70; 35 | -120 - +650 | SL - 80 000 | Groups 2, 4 |
| 57 | T-2 | 450; 800 | 70; 35 | -120 - +650 | SL - 80 000 | Groups 2, 4 |
| 58 | T-4 | 450; 800 | 70; 35 | -120 - +650 | SL - 80 000 | Groups 2, 4 |
| 59 | T-5 | 50 | 40 | -50 - +650 | SL - 80 000 | Group 3 |
| 60 | T-6 | 375 | 70 | -30 - +300 | SL - 90 000 | Group 3 Plume Studies |
| 61 | J-1 | 500; 700; 1400 | 120; 40; 13 | -65 - +750 | SL - 80 000 | Groups 1, 2 |
| 62 | J-2 | 500; 700; 1400 | 120; 85; 35 | -10 - +750 | SL - 80 000 | Groups 1, 2 |
| 63 | ASTF C-1 | 1100; 1460 | 130; 40 | -100 - +1020 | 100 000 | Groups 1, 2 Full Transient Cap. |
| 64 | ASTF C-2 | 1460; 2760 | 50; atm inbleed | -100 - +650 | 100 000 | Groups 1, 2, 4 Full Transient Cap. |

## ALTITUDE ENGINE TEST FACILITIES

| Page Number | Location and Facility Description | Mass Flow (lb/sec) | Pressure (psia) | Temperature (°F) | Altitude Range (ft) | Comments and Groupings |
|---|---|---|---|---|---|---|
| | U.S. DOD | | | | | |
| | Naval Air Propulsion Center | | | | | |
| 65 | 2E | 430 | 41 | -65 - +390 | SL - 80 000 | Group 3 Icing |
| 66 | 1E | 430 | 41 | -65 - +390 | SL - 80 000 | Group 3 Icing |
| 67 | 3W | 100 | 41 | -65 - +220 | 80 000 | Group 1 Icing |
| 68 | 3E | 700 | 30 | -65 - +650 | 100 000 | Group 2 |
| 69 | 4W | 100 | 41 | -65 - +220 | 80 000 | Group 3 |
| 70 | 5W | 100 | 41 | -65 - +220 | 80 000 | Group 3 |
| 71 | 6W | 100 | 41 | -65 - +220 | 80 000 | Group 3 |
| | U.S. INDUSTRY | | | | | |
| | Allison Gas Turbine Operations | | | | | |
| 72 | 871 | 120 | 2.2 - 30 | -75 - +160 | SL - 50 000 | Group 3 Turbo-shaft 15 000 HA |
| 73 | 872 | 120 | 2.2 - 30 | -75 - +160 | SL - 50 000 | Group 3 Turbo-shaft 8000 HA |
| 74 | 873 | 120 | 2.2 - 80 | -75 - +160 | SL - 45 000 | Group 3 Turbo-shaft 10 000 HA |
| 75 | 881 | 420 | 1.7 - 26.5 | -40 - +210 | SL - 50 000 | Group 3 |
| 76 | 885 | 10 | 5.5 - 30 | -75 - +160 | SL - 25 000 | Group 3 Turbo-shaft 800 HP |

## ALTITUDE ENGINE TEST FACILITIES

| Page Number | Location and Facility Description | Mass Flow (lb/sec) | Pressure (psia) | Temperature (°F) | Altitude Range (ft) | Comments and Groupings |
|---|---|---|---|---|---|---|
| | U.S. INDUSTRY | | | | | |
| | General Electric | | | | | |
| 77 | TC-43 and TC-44 | 450 - 1000 | 60 - 43 | +100 - +650 | 60 000 | Group 2 |
| 78 | TC A1 | 175 | 100 | -70 - +400 | 85 000 | Group 3 |
| 79 | TC-40 | 450 @ 60 psia; 1200 @ SLS | 60 | -100 - +400 | 600 (only) | Group 3 |
| | Marquardt Company | | | | | |
| 80 | TC-2 | 400 | To 1500 | To +5000 | To 110 000 | Group 4<br>Blowdown |
| 81 | TC-8 | 1200 | To 300 | To +5000 | To 100 000 | Group 4<br>Blowdown |
| | Pratt & Whitney | | | | | |
| 82 | X-217 | 750; 1200 | 12.5; 12.5 | -10 - +90 | SL - 40 000 | Group 1 |
| 83 | X-218 | 750; 1200 | 12.5; 12.5 | -10 - +90 | SL - 40 000 | Group 1<br>Transient Testing |
| 84 | X-207 | 200; 325; 580 | 45; 35; 12.5 | -20; +625; +280 | SL - 80 000 | Group 2 |
| 85 | X-208 | 200; 325; 580 | 45; 35; 12.5 | -20; +625; +280 | SL - 80 000 | Group 2 |
| 86 | X-209 | 200; 325; 125 | 125; 35; 12.5 | -20; +725; +650 | SL - 80 000 | Group 3 |
| | CANADA | | | | | |
| | National Research Council | | | | | |
| 87 | Alt. Test Chamber | 0 - 12 | 1 - 160 | -70 - +212 | SL - 45 000 | Group 3 |

## ALTITUDE ENGINE TEST FACILITIES

| Page Number | Location and Facility Description | Mass Flow (lb/sec) | Pressure (psia) | Temperature (°F) | Altitude Range (ft) | Comments and Groupings |
|---|---|---|---|---|---|---|
| | FRANCE | | | | | |
| | CEPr | | | | | |
| 88 | R-3 | 441 | 30 | -85 - +390 | 65 600 | Groups 3, 4 |
| 88 | R-4 | 441 | 30 | -85 - +370 | 65 600 | Groups 3, 4 |
| 89 | R-5 | 825 | 100 | +1200 | 65 600 | Groups 2, 4 |
| 90 | S1 | 221 | 29 | +661 | 62 000 | Groups 3, 4 |
| 89 | C-1 | 121 | 17 | -86 - +175 | 36 000 | Groups 3, 4 |
| | GERMANY | | | | | |
| | University of Stuttgart | | | | | |
| 91 | HPT | 154 | 28 | -100 - +350 | 65 600 | Groups 3, 4 |
| | JAPAN | | | | | |
| | Mitsubishi Heavy Industries | | | | | |
| 92 | 1007 | 12 | 33 | -50 - +180 | SL - 20 000 | Group 3 |
| | UNITED KINGDOM | | | | | |
| | Royal Aircraft Establishment | | | | | |
| 93 | ATF C-2 | 450 | 2 - 100 | Ambient - +450 | 50 000 | Group 3<br>Direct Connect |
| 94 | ATF C-3 | 600 | 2 - 39 | -100 - +880 | 65 000 | Groups 2, 4<br>Direct Connect |

## ALTITUDE ENGINE TEST FACILITIES

| Page Number | Location and Facility Description | Mass Flow (lb/sec) | Pressure (psia) | Temperature (°F) | Altitude Range (ft) | Comments and Groupings |
|---|---|---|---|---|---|---|
| | UNITED KINGDOM | | | | | |
| 95 | ATF C-4 | 500 | 3 - 40 | Ambient - +880 | 100 000 | Group 4<br>No Direct Connect |
| 96 | ATF C-3W | 1400 | 2 - atmos | -50 - ambient | 50 000 | Group 4 Icing |
| 97 | ATF C-1 | 450 | 2 - 100 | Ambient - +450 | 50 000 | Group 4 |
| | Rolls Royce | | | | | |
| 98 | ATF C-1 | 400 | 73 | -113 - +355 | 70 000 | Groups 3, 4 |
| 98 | TP 131A | 400 | 165 | +841 | 90 000 | Group 4<br>Blowdown |
| 99 | ATF C-2 | 400 | 73 | -113 - +355 | 70 000 | Groups 3, 4 |

## ENGINE COMPONENT FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) |
|---|---|---|---|---|---|---|
| | U.S. NASA | | | | | |
| | Lewis Research Center | | | | | |
| | Turbine Component Research Facilities | | | | | |
| 104 | Turbine Heat Transfer Fundamentals Facilities | 7 | N/A | Atmospheric | Atmospheric | N/A |
| 110 | Turbomachinery Aerodynamic Laser Anemometer Facility | 10 | N/A | Ambient | Atmospheric | N/A |
| 105 | Hot Cascade 2D Cascade Facility | 15 | N/A | 2500 | 8 | N/A |
| 106 | Small Uncooled Turbine Facilities | 2 ½ | 45 | 150 | 3 ½ | 45 000 |
| 107 | Small Warm Turbine Facility | 8 | 1250 | 800 | 8 | 60 000 |
| 108 | High-Pressure Turbine Hot Section Facility | 200 | 35 000 | 2500 | 20 | 23 000 |
| 109 | Large Warm Turbine Facilities | 25 | 5000 | 950 | 3 | 25 000 |
| | Compressor Component Research Facilities | | | | | |
| 126 | Large Low-Speed Centrifugal Compressor Facility | 66 | 1500 | Ambient | Atmospheric inlet up to 1.18 press. ratio | Up to 2050 |
| 127 | Transonic Oscillating Cascade Facility | 950 ft/sec air velocity | 100 | Ambient | Atmospheric inlet and exhaust | |

## ENGINE COMPONENT FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) |
|---|---|---|---|---|---|---|
| | U.S. NASA | | | | | |
| 128 | Multistage Axial Flow Compressor Facility | Ambient - 100 | 1500 | Ambient | 0.3 - 5.3 inlet | Up to 18 700 |
| 129 | Small Multistage Compressor Facility | 13 | 6000 | Ambient 12 000 outlet temp | 1.1 - 1.7 inlet plenum press up to 30:1 press ratio | Up to 60 000 |
| 130 | Small Centrifugal Compressor Facility | 13 | 3000 | Ambient | 0.1 - 1.0 inlet | Up to 60 000 |
| 131 | Small Single-Stage Centrifugal Compressor Facility | 2 | Turbine drive | +40 - ambient | 0.1 - 1.3 inlet | Up to 100 000 |
| 132 | Single-Stage Axial Flow Compressor | 100 | 3000 | Ambient | 0.3 - 1.0 inlet plenum press | Up to 19 600 |
| 133 | Coaxial Jet Facility | Core: 30<br>Fan: 30 | – | Core: 1500<br>Fan: 1500 | 3:1 press. ratio | – |
| 134 | Fan Acoustic Facility | 80 | 7000 | Ambient | Atmospheric inlet/exhaust up to 2.5 press. ratio | Up to 20 000 |
| | Combustor Component Research Facility | | | | | |
| 152 | Low-Pressure Combustor Facilities | A: 10<br>B: 3 | N/A<br>N/A | 1100<br>1800 | 10<br>10 | N/A<br>N/A |
| 153 | Medium-Pressure Combustor Facilities | 20 | N/A | Ambient - 1100 | 30 | N/A |

## ENGINE COMPONENT FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) |
|---|---|---|---|---|---|---|
| | U.S. NASA | | | | | |
| 154 | High-Pressure Combustor Facility (HPC) | 200 | N/A | Ambient - 850 | 20 operational<br>40 standby | N/A |
| | U.S. DOD | | | | | |
| | Wright Aeronautical Labs | | | | | |
| | Compressor Component Research Facilities | | | | | |
| 135 | Compressor Test Facility | 60 | – | Ambient | 1 | 6000 - 21 500 |
| 136 | Compressor Research Facility | 500 | 30 000 | Ambient | 1 | 2000 - 3000 |
| | Combustor Component Research Facilities | | | | | |
| 155 | Combustion Research Tunnel | 7 ½ | N/A | Ambient | Atmospheric | N/A |
| | U.S. INDUSTRY | | | | | |
| | Garrett Turbine Engine Company | | | | | |
| | Turbine Component Research Facilities | | | | | |
| 111 | (Cooled) Hot Turbine and Cascade Test Facility | 22 | 3000 | 2800 | 20 | 43 000 |
| 112 | Cold Air Turbine Mapping Facility | 6 | 400 | 600 | 125 psia | 60 000 |

ENGINE COMPONENT FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) |
|---|---|---|---|---|---|---|
| | U.S. INDUSTRY | | | | | |
| | Compressor Component Research Facilities | | | | | |
| 137 | C-226 Compressor/Fan Test Facility | 30 | 600; 6000 | Atmospheric inlet; 20 exhaust | Atmospheric | 85 000; 21 000 |
| 138 | C-114, C-113 Compressor Test Facility | 30 | 600; 6000 | Atmospheric inlet; 20 exhaust | Atmospheric | 85 000; 21 000 |
| 139 | Site A Fan Test Facility | 180 | 8000 | Atmospheric | 2 | 11 000 - 21 000 |
| | Combustor Component Research Facilities | | | | | |
| 156 | C-100 Combustion Test Facility | 18 | N/A | 60 - 2000 | 20 | N/A |
| | General Electric | | | | | |
| | Turbine Component Research Facilities | | | | | |
| 113 | Cell A7 Air Turbine Test Facility | 70 | 15 000 | 100 - 1000 | 8 | 15 000 |
| | Compressor Component Research Facilities | | | | | |
| 139 | Full-Scale Compressor Test/ Large Fan Test Facility (FSCT/LFTF) | 1700 fan/ 400 Compressor | 48 000 | -70 to ambient | Atmospheric | 4000 - 15 000 |

## ENGINE COMPONENT FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) |
|---|---|---|---|---|---|---|
| | U.S. INDUSTRY | | | | | |
| | Pratt & Whitney | | | | | |
| | Turbine Component Research Facilities | | | | | |
| 114 | X-203 Test Stand | 400; 125 | 10 000 - 20 000 | -50 - +800 | 1.3; 7 atm | 600 - 15 000 |
| 115 | X-212 Test Stand | 225; 125; 84 | 4000 - 10 500 | +1200 | 2, 8, .9 | 5000 - 15 000 |
| | Compressor Component Research Facilities | | | | | |
| 140 | B33A Stand | – | 6000 | Ambient | Atmospheric | 26 000 |
| 141 | X-204 Test Stand | 210; 40 | 21 600 max | -50 - +220 | 22.5"; 40" HgA | 7200; 15 000 |
| 142 | X-211 Test Stand | 550 | 40 000 | Ambient - 250 | Atmospheric | 5000 - 10 989 |
| | Combustor Component Research Facilities | | | | | |
| 157 | High-Pressure Combustor Lab | 100 | N/A | 450 - 1200 | 44.2 | N/A |
| | Southwest Research Institute | | | | | |
| | Combustor Component Research Facilities | | | | | |
| 158 | Army Fuels and Lubricants Lab, Combustor Test Facility | 2.5 | N/A | -65 - +1500 | 16 | N/A |

ENGINE COMPONENT FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) |
|---|---|---|---|---|---|---|
| | U.S. INDUSTRY | | | | | |
| | Telydyne CAE | | | | | |
| | Turbine Component Research Facilities | | | | | |
| 116 | Hot Cascade Test Stand | 2 | N/A | 3000 | 7 | N/A |
| 117 | Turbine 1 and Turbine 2 Cold Flow Rig | 25 | 300; 2400; 450 | Ambient - 300 | 1.7 | 45 000; 23 000; 11 500 |
| | Compressor Component Research Facilities | | | | | |
| 143 | 3500 hp Compressor Test Stand | 22 | 3500 | -60 - +110 | 1.5 | 39 000 |
| 144 | 1400-1 and 1400-2 Compressor Test Stands | 22 | 1200; 420 | -65 - +235 | 1.5 | 42 000; 70 000 |
| | Combustor Component Research Facilities | | | | | |
| 159 | Combustor Cell | 4; 22 | N/A | -65 - +500 | 6; 1.7 | N/A |
| | Westinghouse Combustion Turbine Systems | | | | | |
| | Turbine Component Research Facilities | | | | | |
| 118 | Vane Cooling Development Rig | 90 | N/A | 2200 | 20 | N/A |
| 119 | Aerodynamic Cascade Test Rig Row One Turbine Vane | 90 | N/A | 900 | 8 | N/A |

ENGINE COMPONENT FACILITIES

| Page Number | Location and Facility Description | Max. Flow (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) |
|---|---|---|---|---|---|---|
| | U.S. INDUSTRY | | | | | |
| | Compressor Component Research Facilities | | | | | |
| 145 | Combustion Turbine Development Center | | 25 000 | | | 12 000 - 4100 |
| | Combustor Component Research Facility | | | | | |
| 160 | Full-Scale Cylindrical Reverse Flow Rig | 90 | N/A | 900 | 20 | N/A |
| | U.S. UNIVERSITY | | | | | |
| | Massachusetts Institute of Technology | | | | | |
| | Turbine Component Research Facilities | | | | | |
| 120 | Blowdown Turbine Facility | 64<br>200 scaled | 2000<br>52 000 scaled | 500<br>4000 scaled | 10<br>40 scaled | 7000<br>14 000 scaled |
| | Compressor Component Research Facilities | | | | | |
| 146 | Blowdown Compressor Facility | 100 scaled | | 212 (max) | 1 | 22 000 |
| | JAPAN | | | | | |
| | Ihi Mizuho Plant | | | | | |
| | Turbine Component Research Facilities | | | | | |
| 121 | High-Pressure Turbine Facility (HPT) | 40 | 6000 | 2500 | 3.5 | 15 000 |

## ENGINE COMPONENT FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) |
|---|---|---|---|---|---|---|
| | **JAPAN** | | | | | |
| | Compressor Component Research Facilities | | | | | |
| 148 | Large-Scale Aeroengine Compressor Facility | 310 | 18 000 | Ambient | 2 | 13 000 |
| | Combustor Component Research Facilities | | | | | |
| 161 | Medium-Pressure Combustor Facility (MPC) | 24 | N/A | 180 - 780 | 7 | N/A |
| | National Aerospace Laboratory | | | | | |
| | Turbine Component Research Facilities | | | | | |
| 122 | High-Temperature Turbine Cooling Facility | 3.7 | N/A | 2200 | 9 | N/A |
| | Compressor Component Research Facilities | | | | | |
| 147 | Fan/Compressor/Turbine Facility | – | 2160 | Ambient | Ambient | 15 500 |
| | Combustor Component Research Facilities | | | | | |
| 162 | High-Pressure Annular Combustor Test Facility | 30 | N/A | 730 | 9 | N/A |
| 163 | High-Pressure Combustor Test Facility | 8.8 | N/A | Ambient - 850 | 50 | N/A |

| 2 | 1 PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 4 | DYNAMIC PRES: ($lb/ft^2$) 8 | 14 |
| | DATE BUILT/UPGRADED: 5 | ALTITUDE RANGE: (ft) 9 | |
| 3 | REPLACEMENT COST: 6 | TEMPERATURE RANGE: (°F) 10 | |
| | OPERATIONAL STATUS: 7 | PRESSURE RANGE: (psia) 11 | |
| | | SPEED RANGE: (Mach No.) 12 | |
| | 13 | | |

TESTING CAPABILITIES: Provides detailed information about the facility. Unique features and special instrumentation are discussed, as well as performance capabilities.

DATA ACQUISITION: Describes the type of systems used for data gathering, the number of channels available, and the form of output.

CURRENT PROGRAMS: Outlines in general language the types of testing currently being conducted in the facilities.

PLANNED IMPROVEMENTS: Describes major improvements, rehabilitations, and modifications being made or being planned on the facility up to Fiscal Year 1986.

LOCAL INFORMATION CONTACT: Lists the name, title, address, and phone number of the person to contact for additional information on the facility.

# EXPLANATION OF AIRBREATHING PROPULSION FACILITIES DATA SHEETS

The box at the top of the data sheet is designed to provide a quick-glance digest of the facility's most pertinent characteristics. The quantitative information in the center section is divided into halves. The right portion contains the salient technical parameters depicting the facility's principal capabilities and operating range. The left portion provides some background and operational information.

The following descriptions correspond to the numbered boxes on the opposite page. Because the technical parameters represented in some of the boxes may differ across the various categories of airbreathing facilities, more than one description may be indicated for a particular box.

1. *Type of Facility*: Wind Tunnel, Altitude Engine Test, Turbines, Compressors, Combustors.

2. Name of the installation where the facility is located, owner, city and state, or country (when foreign).

3. Proper or generic name of the facility, with additional qualifiers or identifiers as appropriate.

4. *Test Chamber Size*: For Wind Tunnels, the dimensions are given in the order of Height, Width, and Length. For Engine Test facilities, the diameter and length of the test chamber are given in that order.

   *Component Size*: For Component facilities, the diameter of the largest article that can be tested is indicated.

5. *Date Built/Upgraded*: Self-explanatory.

6. *Replacement Cost*: Best estimate of the current value (1985) of the facility. Cost in millions of dollars ($M).

7. *Operational Status*: An indication of a facility's current work load expressed in number of shifts per day or week. Also an indication of whether it is operational or on standby.

8. *Dynamic Pressure*: Wind Tunnels–Given in $lb/ft^2$.

   *Mass Flow*: Altitude Engine Test Facilities–An indication of the amount of air flowing into an engine's inlet. Given in lb/sec.

   *Max. Flow Rate*: Component Facilities–The maximum rate of air flow to which the particular component is exposed. Given in lb/sec.

9. *Altitude Range*: Wind Tunnels and Engine Test Facilities–The altitude range simulated in the test section or chamber of these facilities. Given in feet.

   *Pressure Level*: Component Facilities–The maximum air pressure driving the particular components. Given in atmospheres.

10. *Temperature Range*: The air temperature in the wind tunnel test section or the inlet temperature for the engine and component test facilities. Shown in degrees Fahrenheit.

11. *Pressure Range*: The pressure environment in the wind tunnel or engine test facility test section/chamber. Given in pounds per square inch absolute (psia).

    *Speed Range*: Component Facilities–The rotational speed of the test component in rpm.

12. *Speed Range*: Wind Tunnels and Engine Test Facilities–Air speed in the test section/chamber. Given in Mach number.

    *Power Level*: Component Facilities–The maximum horsepower (hp) level generated by the particular test component (turbine or compressor).

13. This space contains supplementary information on the performance range or special conditions of the facility.

14. *Comparable Facilities*: Other facilities with similar characteristics and which may be used as alternatives. When the number of comparable facilities is large, only the identity of the comparable facility may be given. In the case of the Altitude Engine Test facilities, the group(s) to which that facility belongs is always listed at the bottom of this box. Refer to the introduction and the beginning of each facility section for an explanation of these groups.

# PROPULSION WIND TUNNELS

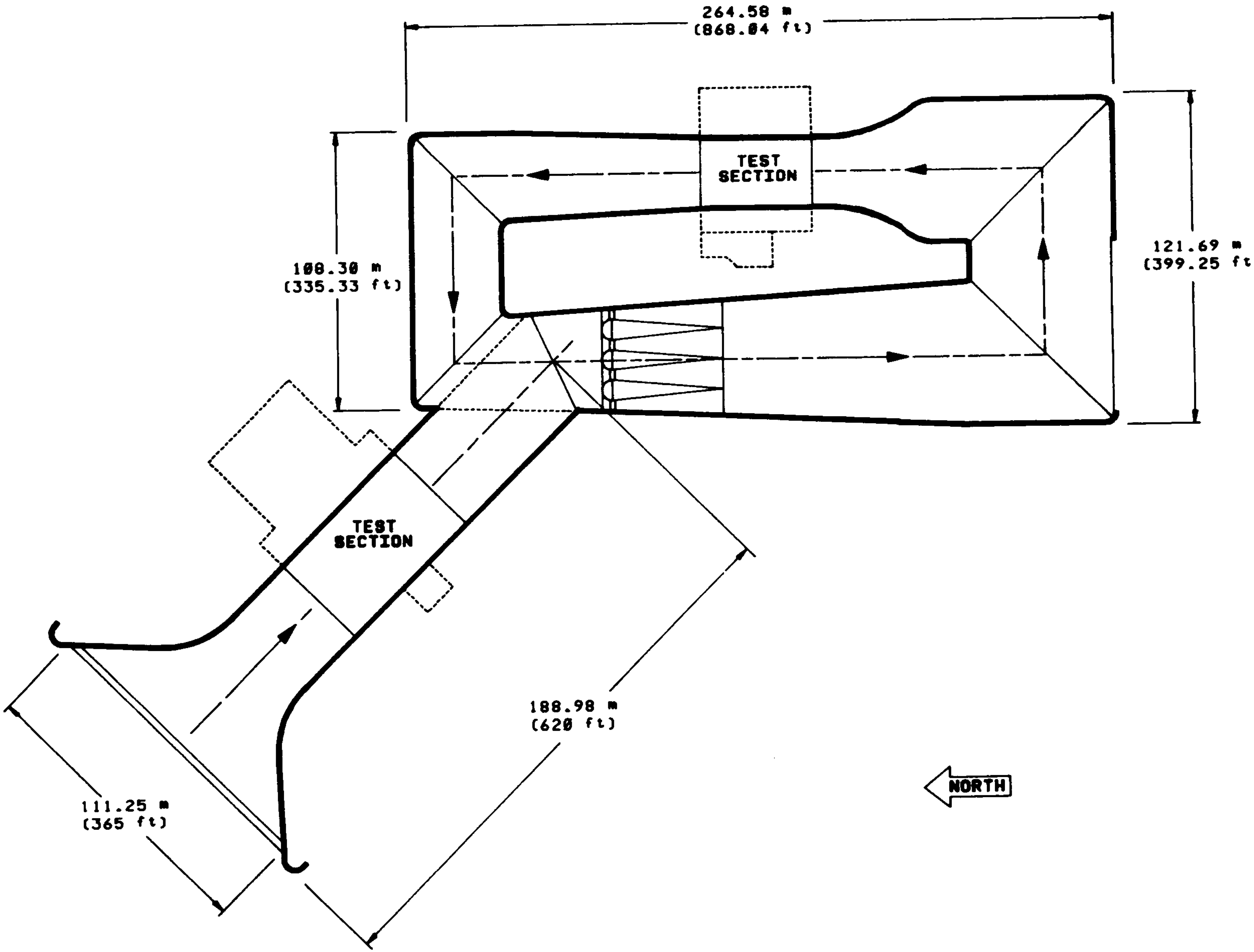
Propulsion testing in wind tunnels allows the engine and its installed inlet to be tested as an integrated system. The propulsion system is presented with an airflow environment similar to that encountered in real flight, where the air is directed around the inlet as well as into it. Other elements of the propulsion system or aircraft are likewise exposed to the same environment and are free to interact with one another as in actual flight conditions. In the larger wind tunnels, the angle of attack also can be varied, resulting in even more realistic airflow conditions for the engines. For complete aerodynamic behavior and propulsion/airframe integration studies, the wind tunnel is not surpassed. The deficiency of wind tunnels for engine testing is their inability to obtain true temperature simulation over a wide operating range. In general, the air in a wind tunnel is not hot enough at the high Mach numbers nor cold enough at the high altitudes and lower Mach numbers. Moreover, conditioning the large volume of air used by the tunnel in addition to that used by the engine itself is a difficult, costly, and inefficient process. Engine test facilities are more economical in this respect for low-bypass engines and generally have better provisions for temperature/altitude simulation.

There are very few true propulsion tunnels in the free world. As listed in Table 2, the majority are in the United States at either NASA or the DOD. The NASA capabilities include the large low-speed 40x80x120 tunnel at Ames, plus the 10x10 and 8x6 ft supersonic tunnels at Lewis. The DOD owns the premier transonic and supersonic facilities at AEDC with their pair of 16 foot tunnels. In the Hypersonic regime, NASA will own the only large facility when the 8 foot High Temperature Tunnel is modified with oxygen enrichment in 1986. The European capability is all low speed and is located in France (S-1 MA) and the Netherlands (DNW). The U.S. industry has a 9x9 ft low-speed facility owned by Boeing and a few small hypersonic tunnels owned by General Applied Sciences. The United States is clearly the leader in this category.

TABLE II

PROPULSION WIND TUNNELS

| Page No. | Facility Designation | Size (ft) | Mach No. | Altitude (ft) | Temp. (°F) | Remarks |
|---|---|---|---|---|---|---|
| 30 | 40 x 80, NASA, ARC | 40 x 80 x 80 L | 0 - 0.4 | – | Ambient | Air Exchange |
| 31 | 80 x 120, NASA, ARC | 80 x 120 x 190 L | 0 - 0.15 | – | Ambient | Single Pass |
| 32 | 10 x 10 SWT,<br>NASA, LeRC | 10 x 10 x 40 L | 2.0 - 3.5 | 77 000 | 60<br>690 | Single Pass |
| 33 | 8 x 6 SWT,<br>NASA, LeRC | 8 x 6 x 39 L | 0.36 - 2.0 | – | 60<br>266 | Single Pass |
| 35 | 16T,<br>AEDC | 16 x 16 x 40 L | 0.06 - 1.6 | 90 000 | 80<br>160 | Exhaust Scoop |
| 34 | 16S,<br>AEDC | 16 x 16 x 40 L | 1.5 - 4.75 | 150 000 | 120<br>620 | Exhaust Scoop |
| 36 | 9 x 9 PWT,<br>Boeing | 9 x 9 x 14.5 L | 0 - 0.33 | – | Ambient | Single Pass |
| 37 | 10 x 20 NRC,<br>Canada | 10 x 20 x 40 L | 0.007 - 0.184 | – | Ambient | Single Pass |
| 38 | S1-MA,<br>France | 20.5 x 22 x 46 L<br>or 26D | 0.023 - 1.0 | 20 000 | 5<br>122 | 20% Air<br>Exchange |
| 41<br>40<br>39 | DNW,<br>Netherlands | 26.5 x 20<br>31 x 31<br>20 x 20 | 0 - 0.4<br>0 - 0.3<br>0 - 0.18 | – | Ambient | Air Exchange |


264.58 m
(868.04 ft)
TEST
SECTION
121.69 m
(399.25 ft)
108.30 m
(335.33 ft)
TEST
SECTION
188.98 m
(620 ft)
111.25 m
(365 ft)
NORTH

| NASA–Ames Research Center, Moffett Field, CA | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 40 x 80 x 80 L | DYNAMIC PRES: ($lb/ft^2$) 0 – 305 | Unique |
| | DATE BUILT/UPGRADED: 1944/1982 | ALTITUDE RANGE: (ft) Atmospheric | |
| 40 x 80-Ft | REPLACEMENT COST: $22M including 80 x 120 | TEMPERATURE RANGE: (°F) Ambient | |
| | OPERATIONAL STATUS: Fiscal Year 1987 | PRESSURE RANGE: (psia) 1 (atmos.) | |
| | | SPEED RANGE: (Mach No.) 0 – 0.4 | |
| | Air exchange | | |

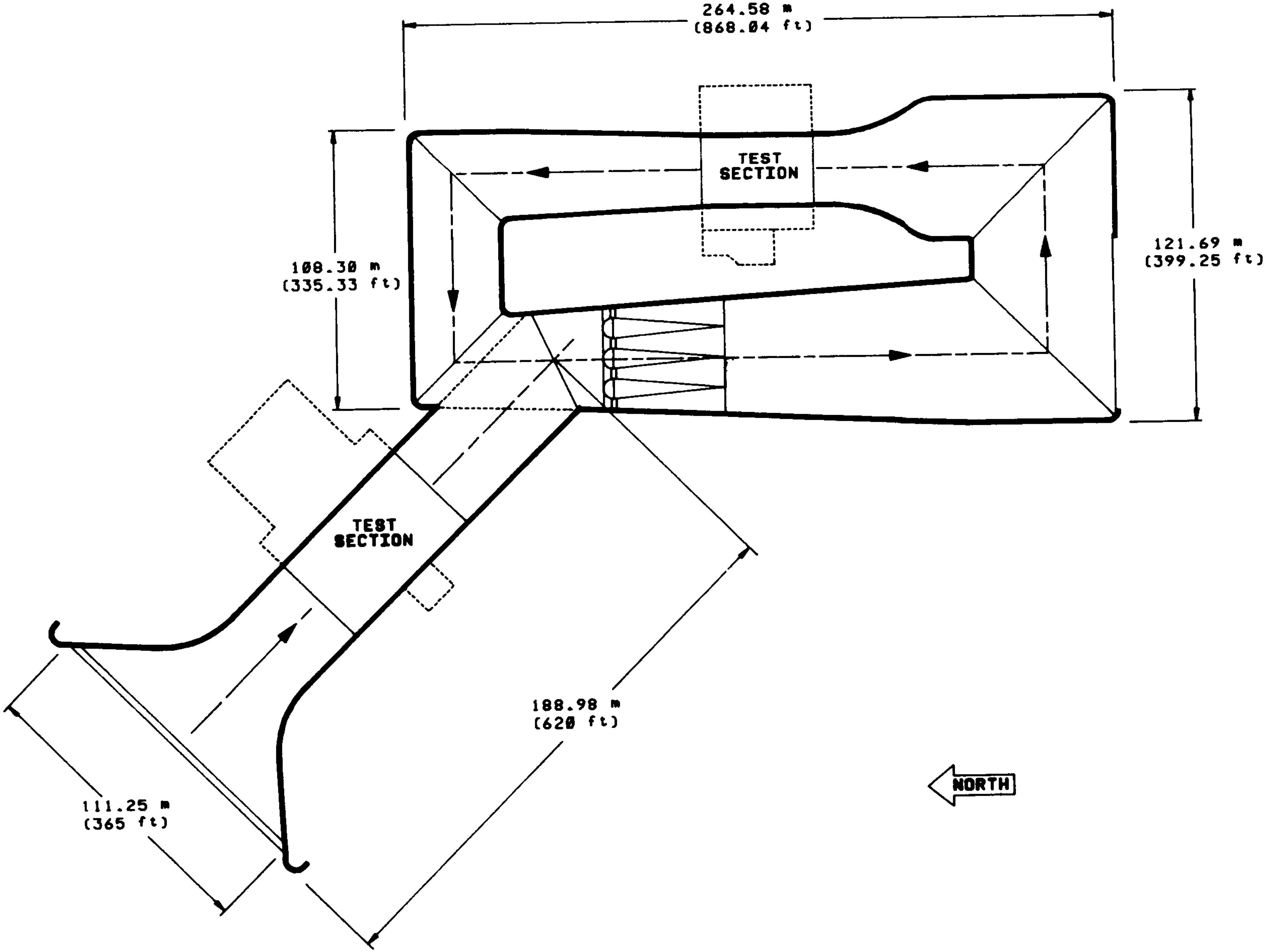
TESTING CAPABILITIES: The 80 x 120-ft Wind Tunnel and the 40 x 80-ft Wind Tunnel share the same drive system, so only one tunnel can be operated at a time. The tunnel is used for full-scale, low-speed V/STOL powered lift investigators and full-scale rotorcraft systems. High-lift devices for takeoff and landing of conventional aircraft are also examined at low forward speed.

DATA ACQUISITION: Data are recorded, processed, and displayed using a distributed data system composed of PDP 11 series and VAX 11/780 processors, which are housed within the 40 x 80-ft Wind Tunnel. Data are transmitted via fiber optics. Graphic displays and hard copy printouts are being implemented at this time. The number of channels available is: up to 1000 for static data and up to 250 for dynamic data. The total sample rate is 1 000 000 samples per second.

CURRENT PROGRAMS: V/STOL aircraft research, augmentor research, high-lift research, and full-scale rotorcraft research.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Jerry V. Kirk, Chief, Low Speed Wind Tunnel Investigations Branch, (415) 965-5045.


264.58 m
(868.04 ft)
121.69 m
(399.25 ft)
108.30 m
(335.33 ft)
TEST
SECTION
TEST
SECTION
188.98 m
(620 ft)
111.25 m
(365 ft)
NORTH

| NASA–Ames Research Center, Moffett Field, CA | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE: (ft)** 80 x 120 x 190 L | **DYNAMIC PRES: (lb/ft$^2$)** 0 – 305 | Unique |
| | **DATE BUILT/UPGRADED:** 1982 | **ALTITUDE RANGE: (ft)** Atmospheric | |
| 80 x 120-Ft | **REPLACEMENT COST:** \$22M including 80 x 40 | **TEMPERATURE RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** Operational Fiscal Year 1987 | **PRESSURE RANGE: (psia)** 1 (atmos.) | |
| | | **SPEED RANGE: (Mach No.)** 0 – 0.15 | |
| | Single pass | | |

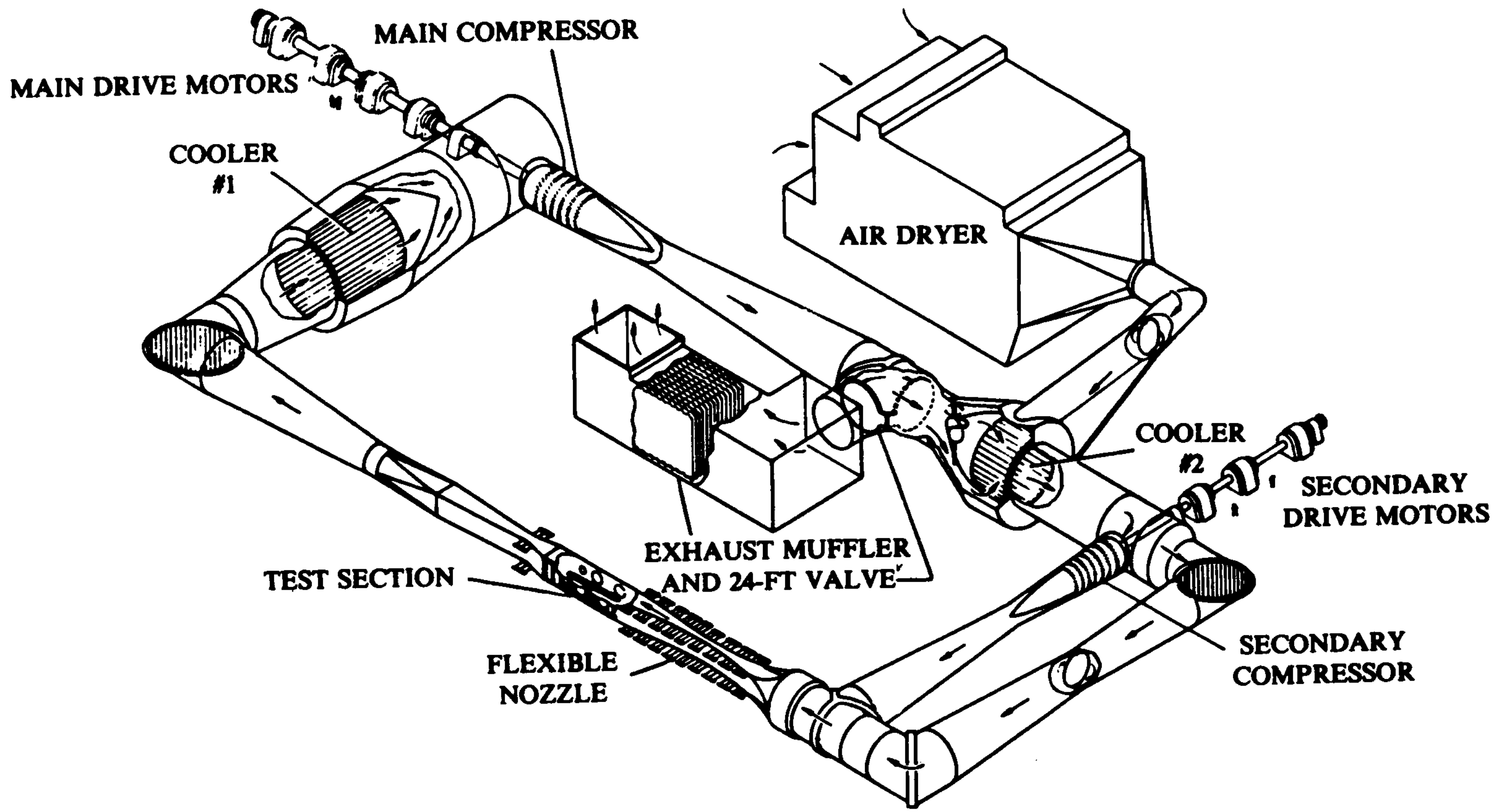
TESTING CAPABILITIES: The 40 x 80-ft Wind Tunnel and 80 x 120-ft Wind Tunnel share the same drive system, so only one can be operated at a time. The tunnel is used for large-scale or full-scale aircraft and rotorcraft research. Measurements taken include force and moment, pressure, dynamic stability, and acoustic signatures. The tunnel is also used extensively for V/STOL powered lift investigations. Full/large-scale propulsion systems are run in the tunnel to determine engine/airframe interactions.

DATA ACQUISITION: Data are recorded, processed, and displayed using a distributed data system composed of PDP 11 series and VAX 11/780 processors, which are housed within the facility. Graphic displays and hard copy printouts are being implemented at this time. The number of channels available is: up to 1000 for static data and up to 250 for dynamic data. The total sampling rate is 1 000 000 samples per second.

CURRENT PROGRAMS: Rotorcraft research for civil and military application; V/STOL powered lift research (augmentor, RALS, etc.).

PLANNED IMPROVEMENTS: Acoustic measurement capability improvements by lowering tunnel background noise and further lowering the turbulence level using antiturbulence screens ahead of the test section.

LOCAL INFORMATION CONTACT: Jerry V. Kirk, Chief, Low Speed Wind Tunnel Investigations Branch, (415) 965-5045.


MAIN COMPRESSOR
MAIN DRIVE MOTORS
COOLER #1
AIR DRYER
COOLER #2
SECONDARY DRIVE MOTORS
EXHAUST MUFFLER AND 24-FT VALVE
TEST SECTION
FLEXIBLE NOZZLE
SECONDARY COMPRESSOR

| NASA–Lewis Research Center, Cleveland, OH | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE: (ft)** 10 x 10 x 40 L | **DYNAMIC PRES: (lb/ft$^2$)** 500 – 600 | Unique |
| | **DATE BUILT/UPGRADED:** 1955 | **ALTITUDE RANGE: (ft)** 77 000 | |
| 10 x 10-Ft Supersonic Wind Tunnel | **REPLACEMENT COST:** $70M | **TEMPERATURE RANGE: (°F)** 60; 690 | |
| | **OPERATIONAL STATUS:** 2 shift operations at 3 runs per week | **PRESSURE RANGE: (psia)** 1.4; 35 | |
| | | **SPEED RANGE: (Mach No.)** 2.0 – 3.5 | |
| | Single pass | | |

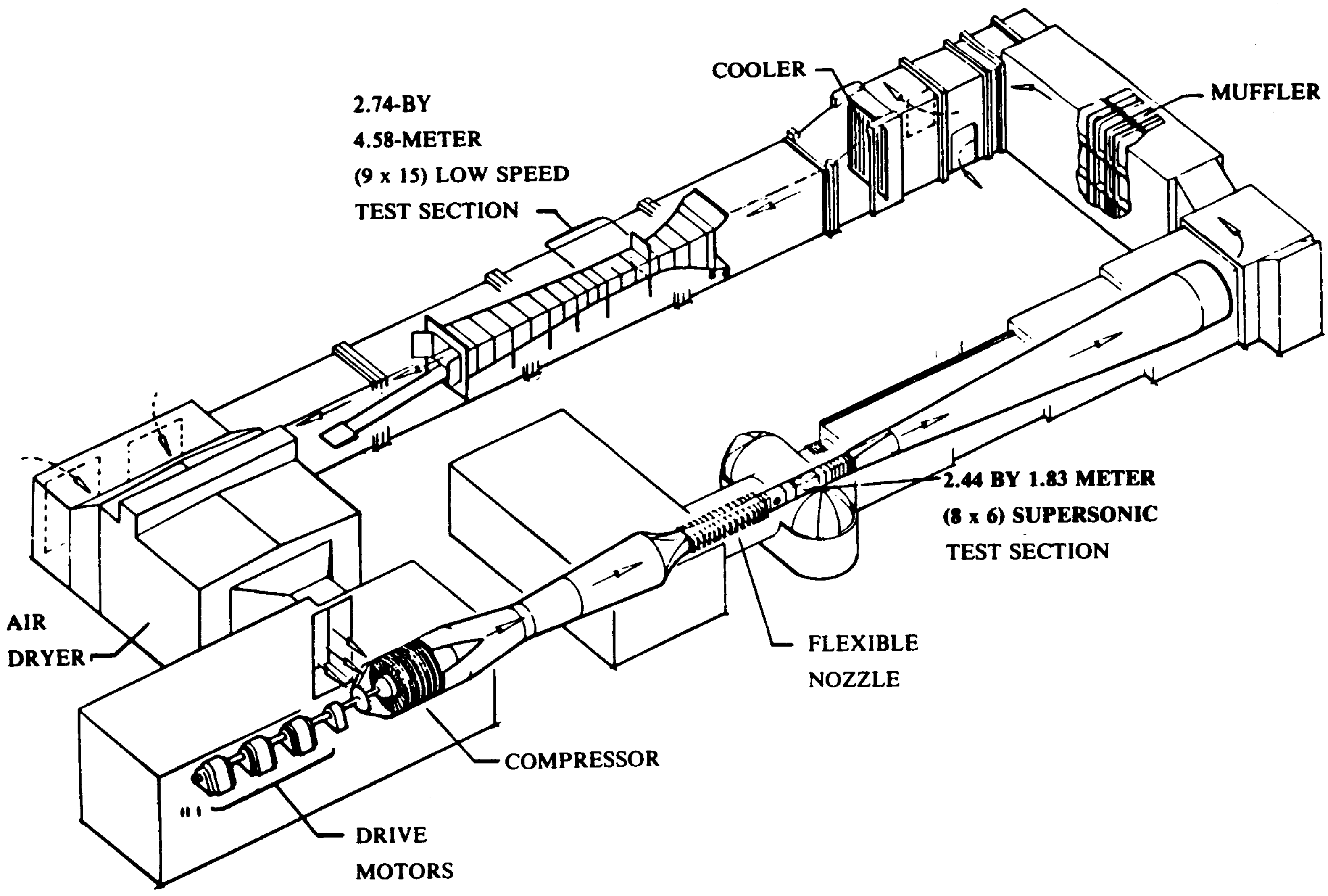
TESTING CAPABILITIES: This tunnel is used for internal flow, pressure, force testing of propulsion systems, and propulsion components, as well as related airframe interaction tests. Internal strain-gage balances are used for measuring force and moments. Propulsion cycle (open circuit) is used for testing burning propulsion systems generating combustion products. Aerodynamic cycle (closed circuit) is used for other tests. Facilities for measuring multiple steady or fluctuating pressures are available.

DATA ACQUISITION: Data are recorded and processed through a dedicated VAX 11/780 computer and centrally (shared) IBM-370 computer system. Alphanumeric and graphic displays can be tailored to the user's requirements in real time.

CURRENT PROGRAMS: Design of advanced propulsion system, support of the Space Transport System programs, support of Advanced Turboprop Program (ATP), code verification test of internal flow of supersonic inlets, and support of DOE.

PLANNED IMPROVEMENTS: Improve data acquisition system to include on-line, real-time color graphics, increased automation of tunnel testing, and color schlieren.

LOCAL INFORMATION CONTACT: Arthur J. Gnecco, Chief, Aeronautics Facilities and Engineering Branch, (216) 433-4000, ext. 5579, FTS 8-294-5579.


2.74-BY
4.58-METER
(9 x 15) LOW SPEED
TEST SECTION
COOLER
MUFFLER
2.44 BY 1.83 METER
(8 x 6) SUPERSONIC
TEST SECTION
FLEXIBLE
NOZZLE
COMPRESSOR
DRIVE
MOTORS
AIR
DRYER

| NASA–Lewis Research Center, Cleveland, OH | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE: (ft)** 8 x 6 x 39 L | **DYNAMIC PRES: (lb/ft$^2$)** 200 – 1240 | Unique |
| | **DATE BUILT/UPGRADED:** 1948 | **ALTITUDE RANGE: (ft)** Atmospheric | |
| 8 x 6-Ft Supersonic Wind Tunnel | **REPLACEMENT COST:** $66M | **TEMPERATURE RANGE: (°F)** 60; 266 | |
| | **OPERATIONAL STATUS:** 2 shift operations at 3 runs per week (backlog) | **PRESSURE RANGE: (psia)** 1.4; 8.5 | |
| | | **SPEED RANGE: (Mach No.)** 0.36 – 2.0 | |
| | Single pass | | |

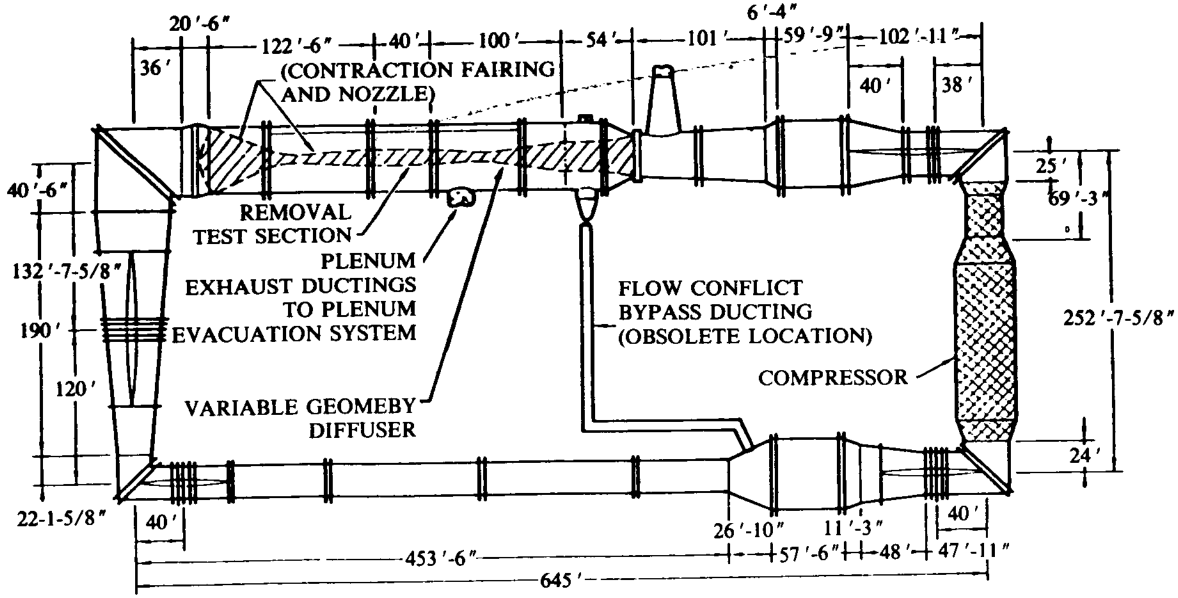
TESTING CAPABILITIES: The tunnel is used for transonic testing of internal flow, pressure, force testing of propulsion systems, and propulsion system components, as well as related airframe interaction tests. Internal strain-gage balances are used for measuring force and moment. Propulsion cycle (open circuit) is used for testing burning propulsion systems generating combustion products. Aerodynamic cycle (closed circuit) is used for other tests. Facilities for measuring multiple steady or fluctuating pressures are available.

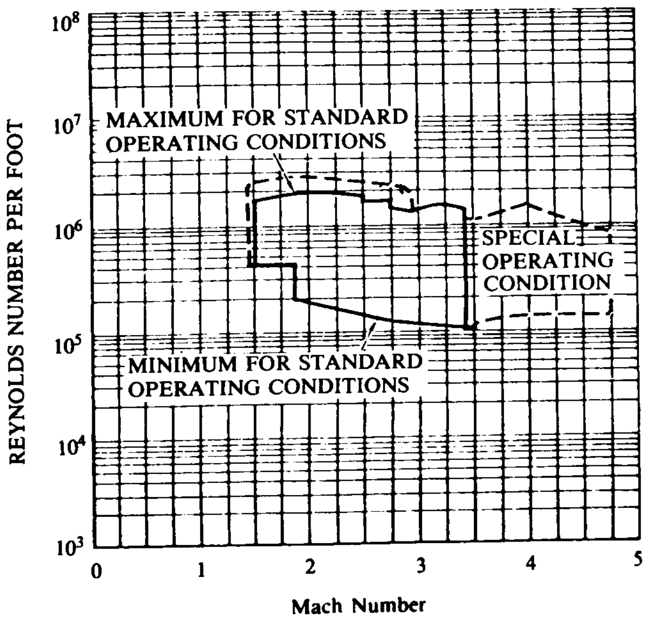
DATA ACQUISITION: Data are recorded and processed through a dedicated VAX 11/780 computer and a centrally (shared) IBM-370 computer system. Alphanumeric and graphic displays can be tailored to the user's requirements in real time.

CURRENT PROGRAMS: Turboprop aeroelastics and acoustics testings, support of the Space Transportation System Program, performance of supersonic drag devices at supersonic speeds, Turboprop Counter Rotation Performance and Noise Tests, and dynamic performance of advanced supersonic inlets.

PLANNED IMPROVEMENTS: Installation of improved on-line data systems including color alphanumeric and color graphics CRT displays.

LOCAL INFORMATION CONTACT: Arthur J. Gnecco, Chief, Aeronautic Facilities and Engineering Branch, (216) 433-4000, ext. 5579, FTS 8-294-5579.




| | |
|---|---|
| MACH RANGE: | 1.5 - 4.75 |
| REYNOLDS NUMBER ($\times 10^6$/ft): | .1 - 2.6 |
| TOTAL PRESSURE (psia): | 1.4 - 16.0 |
| DYNAMIC PRESSURE (psf): | 30 - 570 |
| TOTAL TEMPERATURE (°R): | 560 - 1110 |
| RUN TIME: | CONTINUOUS |

| DOD–Arnold Engineering Development Center, Tullahoma, TN | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE: (ft)** 16 x 16 x 40 L | **DYNAMIC PRES: (lb/ft²)** 30 – 580 | Unique |
| | **DATE BUILT/UPGRADED:** 1954 | **ALTITUDE RANGE: (ft)** 150 000 | |
| 16S | **REPLACEMENT COST:** $550M | **TEMPERATURE RANGE: (°F)** 120; 620 | |
| | **OPERATIONAL STATUS:** Active, lightly scheduled | **PRESSURE RANGE: (psia)** 3.0 – 12.5 | |
| | | **SPEED RANGE: (Mach No.)** 1.5 – 4.75 | |
| | Exhaust scoop | | |

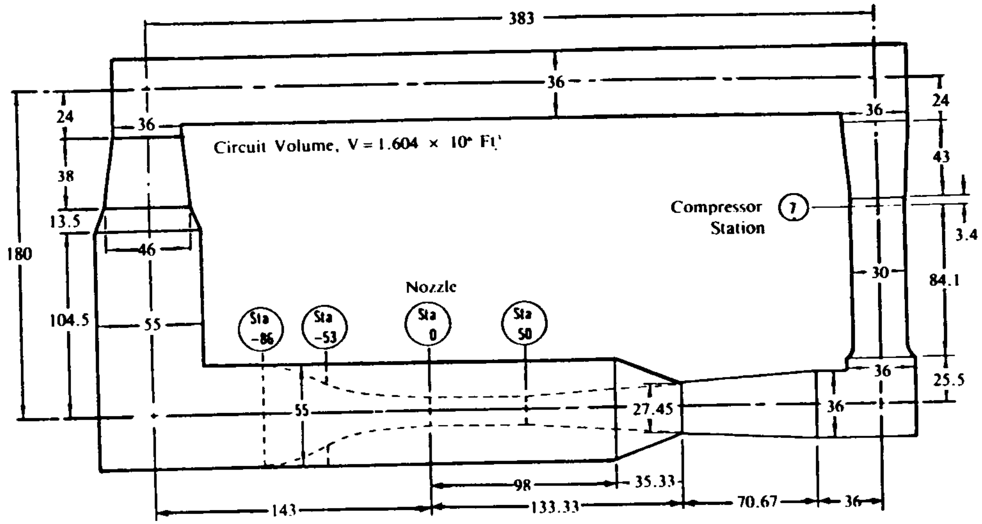
TESTING CAPABILITIES: The tunnel is used for both aerodynamic and propulsion system testing. For aerodynamic testing, the tunnel is used for force and moment, pressure, dynamic stability, internal duct flow, jet effects, and buffet tests. Full-scale tests of operating aircraft propulsion systems permit investigations of engine operations in conjunction with inlets and controls. Removable test sections are contained in test carts that can be transported to a remote model installation building for test article buildup. The flexible plate nozzle sidewalls are positioned by 28 pairs of hydraulic actuators. The tunnel is equipped with a scavenging scoop aft of the test section to capture engine exhaust products. Auxiliary air flows up to 90 lb/sec at 2900 psi can be provided for cold flow jet simulation testing.

DATA ACQUISITION: Digital Equipment Corporation DEC-10 for supervisory control and data management, DEC PDP-15 digital data acquisition system, Computer Automation LSI-2 as digital multiplexer and control, PDP 11/34 digital pressure system, Vector General DD2 graphics system, and Amdahl 5860 central computer.

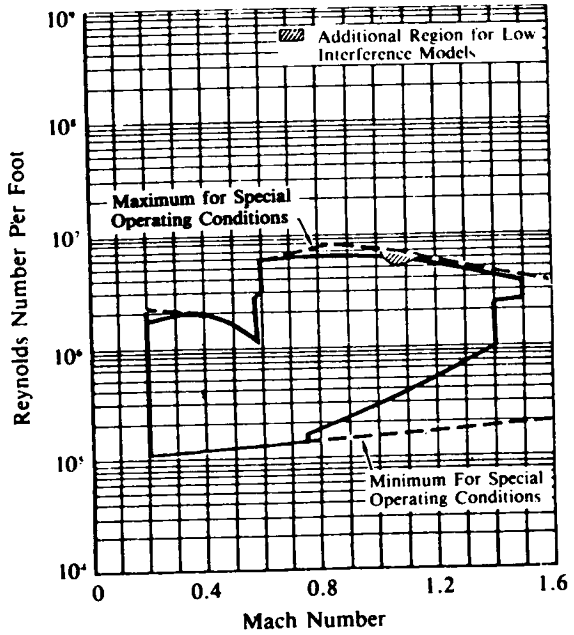
CURRENT PROGRAMS:

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Flight Mechanics Directorate, Deputy for Operations, AEDC/DOF, Arnold AFS, TN 37389, (615) 455-2611, ext. 5280 or 6051.




NOTE: All Dimensions in Feet




| | |
|---|---|
| Mach Range: | 0.2 - 1.6 |
| Reynolds Number ( × 10⁶/ft): | 0.1 - 7.5 |
| **Total Pressure (Psia):** | 0.83 - 27.8 |
| Dynamic Pressure (psf): | 3.3 - 1300 |
| Total Temperature (°P): | 410 - 620 |
| Run Time: | Continuous |

| DOD–Arnold Engineering Development Center (AEDC), Tullahoma, TN | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 16 x 16 x 40 L | DYNAMIC PRES: ($lb/ft^2$) 1.0 – 1000 | Unique |
| | DATE BUILT/UPGRADED: 1954 | ALTITUDE RANGE: (ft) 90 000 | |
| 16T | REPLACEMENT COST: $550M | TEMPERATURE RANGE: (°F) 120; 620 | |
| | OPERATIONAL STATUS: Active, lightly scheduled | PRESSURE RANGE: (psia) 3.0; 12.5 | |
| | | SPEED RANGE: (Mach No.) 1.5 – 4.75 | |
| | Exhaust scoop | | |

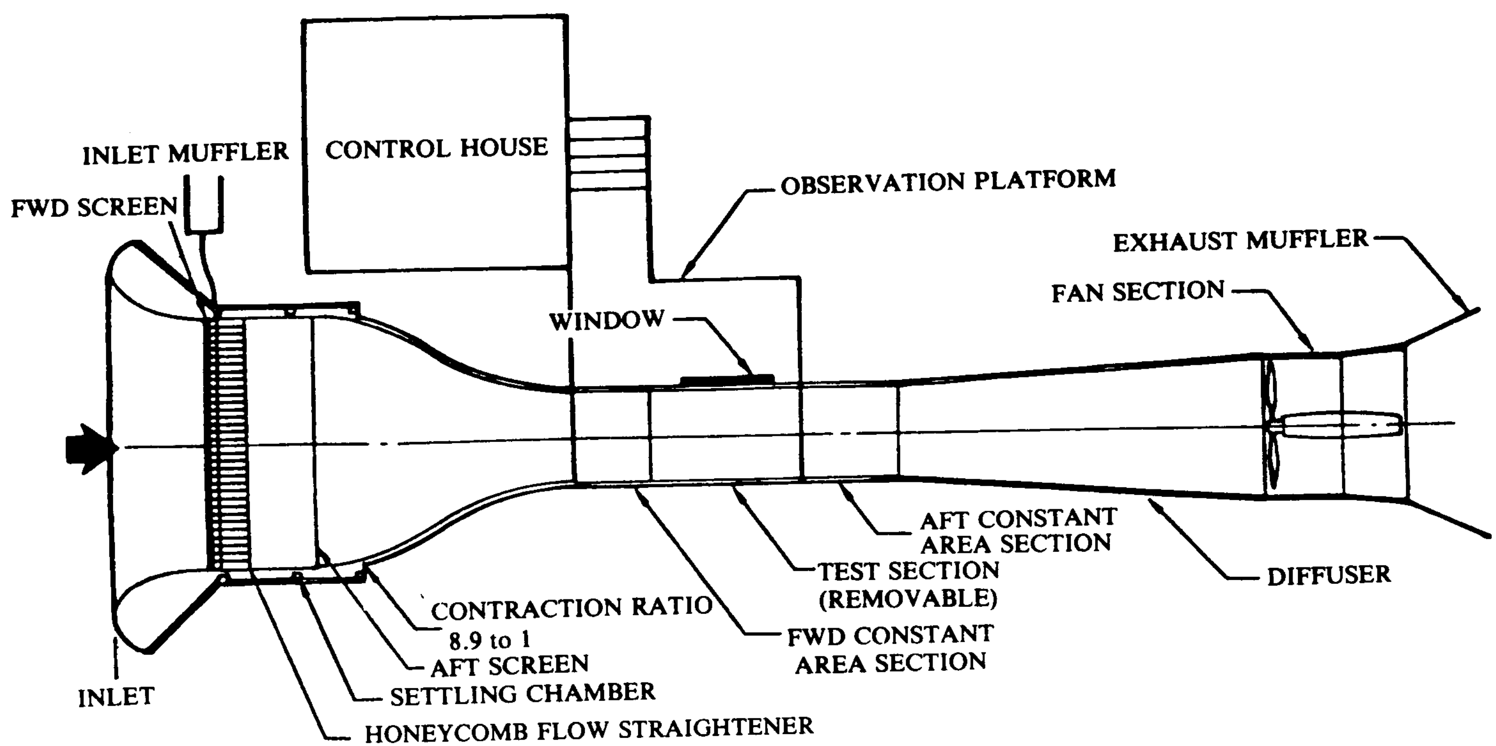
TESTING CAPABILITIES: The tunnel is used for both aerodynamic and propulsion decelerator deployment system testing. For aerodynamic testing, the tunnel is used for force and moment, pressure, dynamic stability, decelerator deployment, internal duct flow, jet effects, and flutter buffet tests. Full-scale tests of operating propulsion systems permit investigations of engine operations in conjunction with their inlets and controls. Removable test sections are contained in 2 test carts that can be transported to a remote model installation building for test article buildup. The test section is equipped with inclined-hole perforated walls. Supersonic conditions are provided by movable sidewall flexible nozzle plates positioned by 15 pairs of electrically driven actuators. The tunnel is equipped with a scavenging scoop aft of the test sections for exhausting engine combustion products. Auxiliary air up to 90 lb/sec at 2900 psi is available for cold flow jet simulation testing.

DATA ACQUISITION: Digital Equipment Corporation DEC-10 for supervisory control and data management, DEC PDP-15 digital data acquisition system, Computer Automation LSI-2 as digital multiplexer and control, PDP 11/34 digital pressure system, Vector General DD2 graphics system, and Amdahl 5860 central computer.

CURRENT PROGRAMS:

PLANNED IMPROVEMENTS: PDP 11/60 process control 1984, high angle automated sting, captive trajectory store separation system, and flow improvement modifications.

LOCAL INFORMATION CONTACT: Flight Mechanics Directorate, Deputy for Operations, AEDC/DOF, Arnold AFS, TN 37389, (615) 455-2611, ext. 5280 or 6051.


INLET MUFFLER
FWD SCREEN
CONTROL HOUSE
OBSERVATION PLATFORM
EXHAUST MUFFLER
FAN SECTION
WINDOW
AFT CONSTANT
AREA SECTION
DIFFUSER
TEST SECTION
(REMOVABLE)
FWD CONSTANT
AREA SECTION
CONTRACTION RATIO
8.9 to 1
AFT SCREEN
SETTLING CHAMBER
HONEYCOMB FLOW STRAIGHTENER
INLET

| Boeing, Seattle, WA | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 9 x 9 x 14.5 L | DYNAMIC PRES: ($lb/ft^2$) 0 – 127 | Unique |
| | DATE BUILT/UPGRADED: 1968: Data System 1980: Rescreen | ALTITUDE RANGE: (ft) Atmospheric | |
| 9 x 9-Ft | REPLACEMENT COST: $46M | TEMPERATURE RANGE: (°F) Ambient | |
| | OPERATIONAL STATUS: 2000 to 3000 hr/year Running 2nd and 3rd shift | PRESSURE RANGE: (psia) 1 (atmos.) | |
| | | SPEED RANGE: (Mach No.) 0 – 0.33 | |
| | Single pass | | |

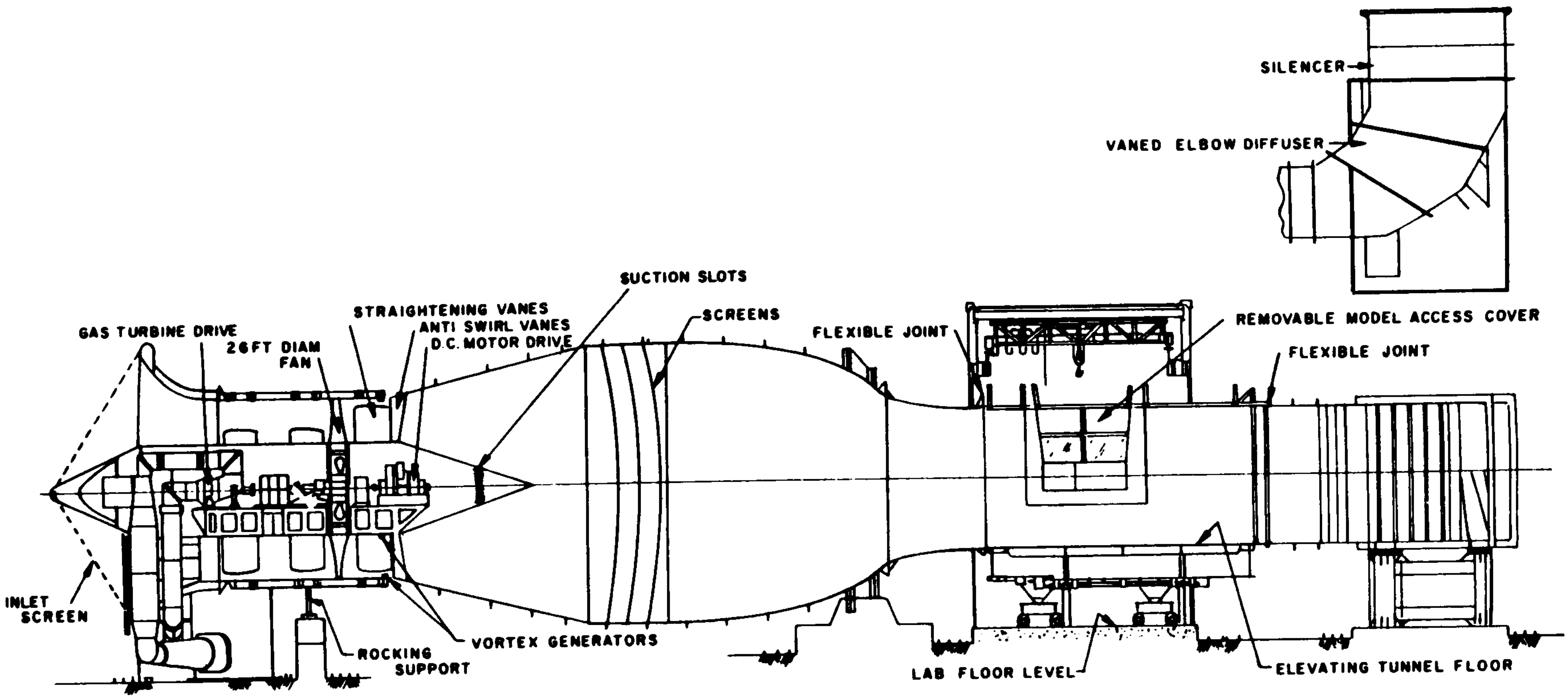
TESTING CAPABILITIES: Models can be sting, horizontal, or vertical ground plane mounted. Each tunnel has a continuous air supply of various flow rates and pressures, can produce products of combustion of 15 lb/sec at 1000° F maximum, a vacuum from 1.5 lb/sec at 2 psia to 12 lb/sec at ambient, and can produce steam at 10 lb/sec superheated at 100 psi and 325° F. Each tunnel is powered by an Allison 501-D13 turboprop engine producing 3000 hp. Tunnel A has extensive internal acoustic treatment, a removable anechoic test section with traversing microphone, and another test section for propulsion thrust reverser reingestion testing. Tunnel B has a wall-mounted pitch mechanism designed for 15-in-diameter inlet models, an inlet suction source provided by a J-47 turbojet engine, and a 6-component balance. Testing in Tunnel A consists of nozzle noise testing, thrust reverser reingestion tests, and half- or full-size models with simulated engine inlet and exhaust conditions. Testing in Tunnel B consists of inlet testing, aerodynamic testing, and models using flow through, blown, or turbopowered simulator nacelles.

DATA ACQUISITION: Two hundred analog channels, 50 digital channels, and 4 scanivalves are available per tunnel. The system is controlled by PDP 8 computers. Data are available immediately.

CURRENT PROGRAMS: Main research is directed at the study of engine inlets, thrust reversers, and nozzle development.

PLANNED IMPROVEMENTS: None at this time.

LOCAL INFORMATION CONTACT: Chief of Propulsion Labs, (206) 655-9416


SILENCER
VANED ELBOW DIFFUSER
SUCTION SLOTS
STRAIGHTENING VANES
ANTI SWIRL VANES
D.C. MOTOR DRIVE
SCREENS
FLEXIBLE JOINT
REMOVABLE MODEL ACCESS COVER
FLEXIBLE JOINT
GAS TURBINE DRIVE
26 FT DIAM FAN
INLET SCREEN
ROCKING SUPPORT
VORTEX GENERATORS
LAB FLOOR LEVEL
ELEVATING TUNNEL FLOOR

| National Research Council, Canada | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE: (ft)** 20 x 10 x 40 L | **DYNAMIC PRES: (lb/ft$^2$)** 0 – 50 | Unique |
| | **DATE BUILT/UPGRADED:** 1962/1967 | **ALTITUDE RANGE: (ft)** Atmospheric | |
| 10 x 20-Ft Propulsion Tunnel | **REPLACEMENT COST:** \$7M | **TEMPERATURE RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** 1 shift per day | **PRESSURE RANGE: (psia)** 1 (atmos.) | |
| | | **SPEED RANGE: (Mach No.)** 0.007 – 0.184 | |
| | Single pass | | |

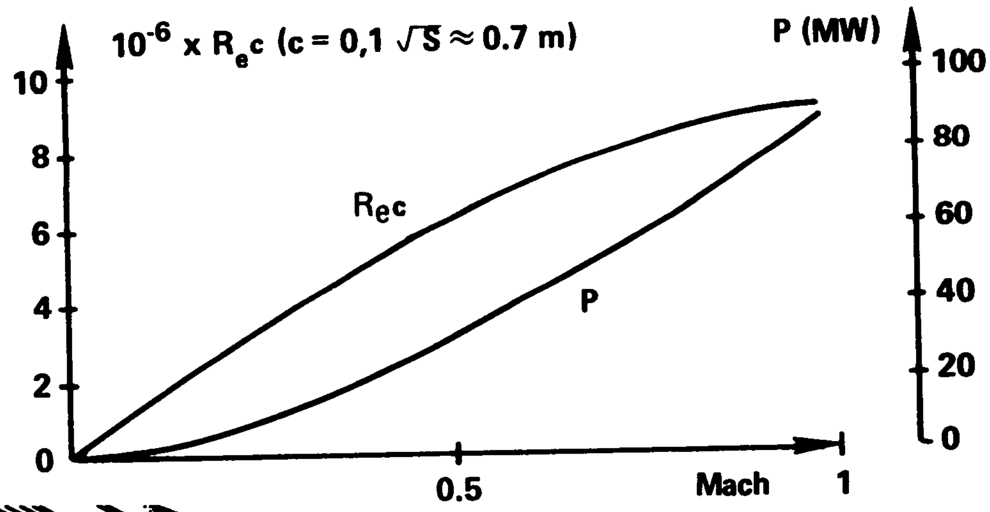
TESTING CAPABILITIES: Originally designed for the testing of V/STOL propulsion systems involving reaction jets. Balance-mounted turbomachinery models of capacities up to several thousand horsepower can be energized using an off-site 5-MW air compressor delivering up to 32 lb/sec at 7 atm. Alternatively, the same equipment can be used to apply suction to models. The 5-component weighbeam balance system can support model weights up to 2 tons. Lift, drag, and pitching moment limits are ±4000, ±2000, and ±5000 lb.ft. A 16-bladed, 26-ft diameter fan located at tunnel entry is driven by a 1000-hp dc motor (up to 90 mph) or by an 8000-hp free gas turbine supplied by an externally housed turbojet (up to 140 mph).

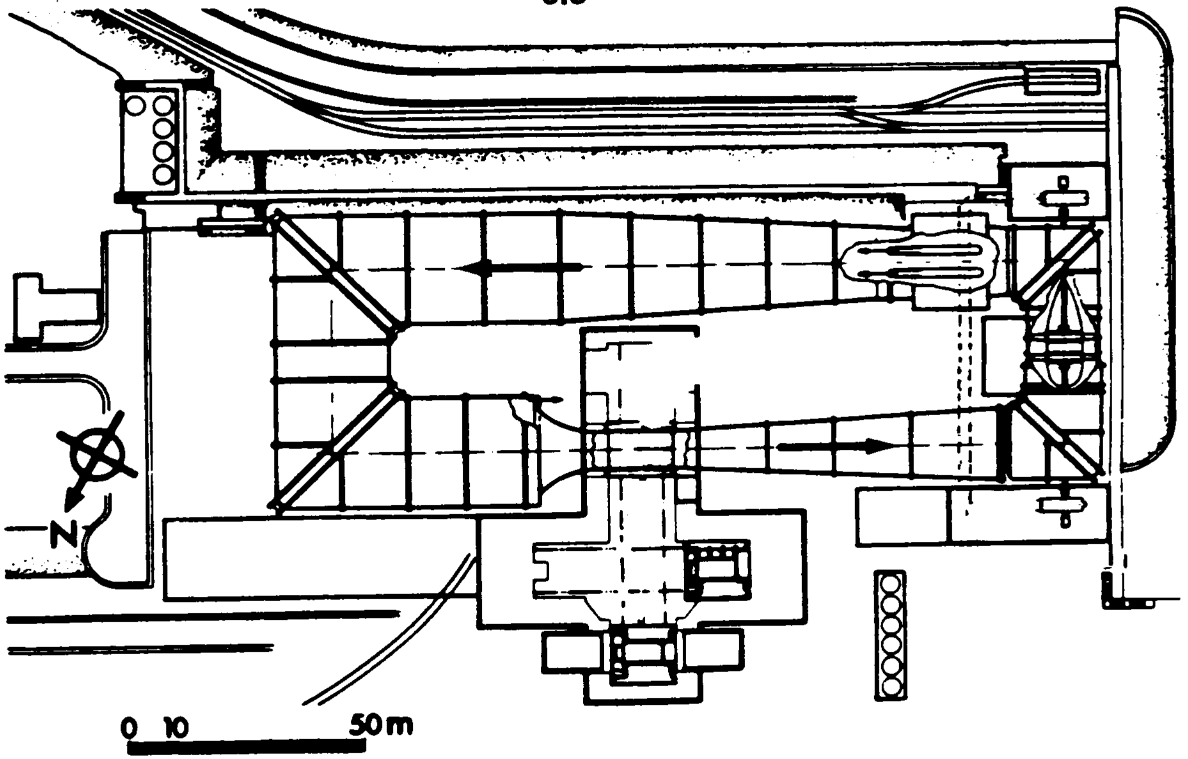
DATA ACQUISITION: Twenty channels of information can be recorded on the data acquisition system and reduced off-site.

CURRENT PROGRAMS: In recent years, the unique characteristics of the facility have been increasingly used in industrial problem areas unrelated to its original purpose. In addition to aeronautical applications, these have included surface transport (full-scale automobiles, snowmobiles, etc.), industrial aerodynamics, wind engineering, etc.

PLANNED IMPROVEMENTS: An additional 7.5-MW compressor is currently being installed with the potential to augment existing compressed-air supplies by 60 lb/sec. Operational, late 1984. Cost, \$3.2M. Preliminary planning on a test-section reconstruction to provide optional 20-ft wide x 10-ft high configuration and upgraded data acquisition system has been completed. Estimated cost \$1.6M.

LOCAL INFORMATION CONTACT: R. A. Tyler, Head, Gas Dynamics Laboratory, National Research Council of Canada, Ottawa, Ontario, K1A OR6, (613) 993-2442.


$10^{-6} \times R_e c$ ($c = 0,1 \sqrt{S} \approx 0.7$ m)
P (MW)
$R_{ec}$
P
0
2
4
6
8
10
0
20
40
60
80
100
0.5
Mach
1


N
0 10 50m

| ONERA, Modane, France | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 20.5 x 22 x 46 L | DYNAMIC PRES: ($kN/m^2$) 0 – 33 | Unique |
| | DATE BUILT/UPGRADED: 1952 | ALTITUDE RANGE: (ft) 20 000 | |
| S1-MA | REPLACEMENT COST: | TEMPERATURE RANGE: (°F) 5; 122 | |
| | OPERATIONAL STATUS: 1 or 2 shifts | PRESSURE RANGE: (psia) 0.9 (atmos.) | |
| | | SPEED RANGE: (Mach No.) 0.023 – 1.0 | |
| | Exhaust scoop | | |

TESTING CAPABILITIES: All conventional aerodynamic measurements on large scale (up to full scale) complete- or half-models including flow survey, wake, and boundary layers measurements. Basic sting support varies angle-of-attack 40° and sideslip ±10°, and turntables up to 360°. Jet engines, full-scale missiles, powered models by air and TPS (60 b, up to 25 kg/sec; basic: 10 kg/sec), propellers (900 kW), and helicopter rotor test rig (550 kW). Air intake measurements; unsteady testing; icing and deicing (in winter); flight mechanic rig, canopy ejection, store launching, parachute, canopy rain visibility, and engine noise.

1st cart: 4 walls added for a reduced semirectangular (H: 6,3; L: 6,7) slotted (4 slots in "corners") test section mainly devoted to high angle-of-attack large combat transonic aircraft and large half-models
2nd cart: Devoted to low-speed tests (150 m/sec). Equipped with a ground floor using boundary-layer bleed
3rd cart: Store launching, icing, propellers and helicopter rotors, large commercial aircraft, engines, and missiles

DATA ACQUISITION: Global forces, local forces, pressures (individual, scanned, unsteady), temperature displacements, deformation, flow, and skin visualizations. Basically 64 analog and digital channels, extension possible with steady or unsteady channels, possibility of very high speed PCM. Local HP-1000 computer for data acquisition and testing devices survey. Local real-time computation by VAX-782.

CURRENT PROGRAMS: Civil aircraft, combat aircraft development, and performance control. Engine, propellers, and helicopter tests; engine and missiles full-scale tests; structures compartment; and nonaeronautic tests.

PLANNED IMPROVEMENTS: Continuous increase of computer-controlled testing devices and improvement of instrumentation.

LOCAL INFORMATION CONTACT: M. Giachetto, ONERA, Centre de Modane-Avrieux, BP 25-73 500 Modane, France.

| NLR and DFVLR, Noordostpolder, Netherlands | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (m) 9.5 x 9.5 x 15 L | DYNAMIC PRES: ($kN/m^2$) 0 – 2.21 | Unique |
| | DATE BUILT/UPGRADED: 1976 | ALTITUDE RANGE: (ft) Atmospheric | |
| DNW 9.5 x 9.5-m | REPLACEMENT COST: | TEMPERATURE RANGE: (°F) Ambient | |
| | OPERATIONAL STATUS: | PRESSURE RANGE: (psia) – | |
| | | SPEED RANGE: (Mach No.) 0 – 0.18 | |

TESTING CAPABILITIES: The largest low-speed tunnel in Western Europe is used for aerodynamic and aeroacoustic tests on aircraft helicopter and nonaeronautical projects. The closed-circuit air exchange tunnel is powered by a variable speed fan driven by a 12.7-MW motor at a maximum speed of 0.5 M. The interchangeable test sections can be prepared in the parking hall adjacent to the tunnel circuit. Models are prepared in large model assembly rooms. The particular model/test section combination is determined by the requirements of each investigation. The test section provides good flow quality (local flow angularity of ±0.1° and turbulence about 0.1%). The open test section provides low background noise in the largest anechoic test chamber in the world. Each test section has a sting support with large angle ranges (±45° and ±30°) and vertical movement compressed high-pressure air for model engine simulators, and a 6-component platform balance.

DATA ACQUISITION: Two computer systems are used. The first system, called MARS, is coupled to the tunnel for tunnel operation and control of data acquisition and reduction. The second system, called VENUS, consists of a main computer and satellite computers. The satellite computers are located in the different model preparation rooms or test sections and support a particular investigation. Data can be acquired on up to 100 channels for each satellite computer.

CURRENT PROGRAMS: General low-speed aircraft aerodynamics, high-lift devices, and V/STOL aerodynamics; engine/airframe interference; airframe, engine, and rotor noise; rotor aerodynamics; and flutter and dynamics test.

PLANNED IMPROVEMENTS:

LOCAL INFORMATION CONTACT:

| NLR and DFVLR, Noordostpolder, Netherlands<br><br>DNW<br>8 x 6-m | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (m) 6 x 8 x 16 L | DYNAMIC PRES: ($kN/m^2$) 7.41 | Unique |
| | DATE BUILT/UPGRADED: 1980 | ALTITUDE RANGE: (ft) Atmospheric | |
| | REPLACEMENT COST: | TEMPERATURE RANGE: (°F) – | |
| | OPERATIONAL STATUS: | PRESSURE RANGE: (psia) – | |
| | | SPEED RANGE: (Mach No.) 0 – 0.3 | |

TESTING CAPABILITIES: The largest low-speed tunnel in Western Europe is used for aerodynamic and aeroacoustic tests on aircraft helicopter and nonaeronautical projects. The closed-circuit air exchange tunnel is powered by a variable speed fan driven by a 12.7-MW motor at a maximum speed of 0.5 M. The interchangeable test sections can be prepared in the parking hall adjacent to the tunnel circuit. Models are prepared in large model assembly rooms. The particular model/test section combination is determined by the requirements of each investigation. The test section provides good flow quality (local flow angularity of ±0.1° and turbulence about 0.1%). The open test section provides low background noise in the largest anechoic test chamber in the world. Each test section has a sting support with large angle ranges (±45° and ±30°) and vertical movement compressed high-pressure air for model engine simulators, and a 6-component platform balance.

DATA ACQUISITION: Two computer systems are used. The first system, called MARS, is coupled to the tunnel for tunnel operation and control of data acquisition and reduction. The second system, called VENUS, consists of a main computer and satellite computers. The satellite computers are located in the different model preparation rooms or test sections and support a particular investigation. Data can be acquired on up to 100 channels for each satellite computer.

CURRENT PROGRAMS: General low-speed aircraft aerodynamics, high-lift devices, and V/STOL aerodynamics; engine/airframe interference; airframe, engine, and rotor noise; rotor aerodynamics; and flutter and dynamics test.

PLANNED IMPROVEMENTS:

LOCAL INFORMATION CONTACT:

| | PROPULSION WIND TUNNELS | | COMPARABLE FACILITIES |
|---|---|---|---|
| NLR and DFVLR, Noordostpolder, Netherlands | TEST CHAMBER SIZE: (m) 6 x 6 | DYNAMIC PRES: ($kN/m^2$) 0 – 12.9 | Unique |
| | DATE BUILT/UPGRADED: | ALTITUDE RANGE: (ft) Atmospheric | |
| DNW 6 x 6-m | REPLACEMENT COST: | TEMPERATURE RANGE: (°F) Ambient | |
| | OPERATIONAL STATUS: | PRESSURE RANGE: (psia) Atmospheric | |
| | | SPEED RANGE: (Mach No.) 0.4 | |
| | Air exchange | | |

TESTING CAPABILITIES: The largest low-speed tunnel in Western Europe is used for aerodynamic and aeroacoustic tests on aircraft helicopter and nonaeronautical projects. The closed-circuit air exchange tunnel is powered by a variable speed fan driven by a 12.7-MW motor at a maximum speed of 0.5 M. The interchangeable test sections can be prepared in the parking hall adjacent to the tunnel circuit. Models are prepared in large model assembly rooms. The particular model/test section combination is determined by the requirements of each investigation. The test section provides good flow quality (local flow angularity of ±0.1° and turbulence about 0.1%). The open test section provides low background noise in the largest anechoic test chamber in the world. Each test section has a sting support with large angle ranges (±45° and ±30°) and vertical movement compressed high-pressure air for model engine simulators, and a 6-component platform balance.

DATA ACQUISITION: Two computer systems are used. The first system, called MARS, is coupled to the tunnel for tunnel operation and control of data acquisition and reduction. The second system, called VENUS, consists of a main computer and satellite computers. The satellite computers are located in the different model preparation rooms or test sections and support a particular investigation. Data can be acquired on up to 100 channels for each satellite computer.

CURRENT PROGRAMS: General low-speed aircraft aerodynamics, high-lift devices, and V/STOL aerodynamics; engine/airframe interference; airframe, engine, and rotor noise; rotor aerodynamics; and flutter and dynamics test.

PLANNED IMPROVEMENTS:

LOCAL INFORMATION CONTACT:

# ALTITUDE ENGINE TEST FACILITIES

Propulsion testing in Altitude Engine Test Facilities falls into two broad categories: direct-connect and freejet testing. In the direct-connect version, air is fed directly into the engine, eliminating (or bypassing) the use of an inlet and avoiding any loss of air flowing around the engine. The intent is to present properly conditioned combustion air to the engine as if an inlet were present but in a more efficient manner. This air is usually presented in an idealized uniform profile, although provisions are often available for introducing temperature and pressure profile distortions. The smaller, more easily controlled volume of air is thereby easier to condition for the temperature extremes (hot or cold) required for true simulation of engine operation at high Mach numbers, or at high altitude and low Mach number. Not all facilities, however, offer all of the desired conditions, either because they were designed for specific applications or because certain limitations were imposed due to cost or the technology available at the time of construction.

In freejet engine test stands, the engine and its inlet are mounted so that the air from a nozzle can impinge on the engine's inlet. This configuration is similar to a wind tunnel, except that the quality of the airflow is seldom as good. However, freejet facilities are still more economical since the air can be directed right at the inlet, and the provisions for good temperature simulation also are available. The angle-of-attack capabilities are generally very limited, but they can be extended in the larger facilities. Generally, a freejet capability is available as an option or specific configuration of a direct-connect facility.

Of the more than 80 engine test facilities examined, about 60 offered altitude simulation capability, and these are included in this catalogue.

## COMPARABLE CAPABILITIES

In order to provide a meaningful comparison of these facilities, they have been categorized into three airflow/Mach number groups, each suitable for testing a particular class of engines. A fourth group of facilities offering freejet capabilities has also been identified and listed. No attempt has been made to differentiate further among the facilities within a particular group as to which offer the best capabilities. Instead, the groups are listed in Tables 3a–d by installation and by size. However, within each facility's Data Sheet, an attempt has been made to indicate those other engine facilities that most closely match its capabilities. These are listed in the Comparable Facilities box, along with an indication of the engine group to which the facility belongs.

The following groups have been defined:

- GROUP 1: Facilities capable of testing large high-bypass turbofan engines at an airflow of 1200 lb/sec or greater and air speeds less than Mach 1.
- GROUP 2: Facilities appropriate for testing large turbojet, small high-bypass turbofan, and low-bypass turbofan engines with an airflow of 480 lb/sec or larger and air speeds of Mach 3.0 or greater.

- GROUP 3: Facilities for testing medium and/or small turbojet engines with an airflow of less than 480 lb/sec and air speeds up to Mach 3.5.
- GROUP 4: Facilities offering a freejet testing capability. Because this may be an additional rather than a sole capability at some facilities, Group 4 contains some facilities that also are listed in the other groups.

High-Flow, High-Bypass, Low-Speed Turbofans (Group 1)

Table 3a lists those facilities capable of testing these large engines. The premier capability in this category resides in the United States at DOD's AEDC. Of the seven test chambers listed, the four with the highest flow are at AEDC. Two of these, ASTF-C1 and C2, are brand-new modern chambers currently being checked out for operations (summer of 1985). The ASTF complex will have full transient test capability, providing for simultaneous programming of engine speed, Mach number, and altitude conditions. Both refrigerated and hot-air conditioning are available, with the latter being necessary in testing at high Mach numbers.

Following AEDC, the next best capability based on airflow is in the United Kingdom at the RAE-Pyestock facilities in Farnborough. Test cell 3W has an airflow capacity of 1390 lb/sec, a very respectable capability in this category. American industry also has some good capabilities in this category at the Pratt & Whitney Willgoos Laboratories' test cells X217 and X218. These facilities can deliver an airflow of 1200 lb/sec, with test cell X218 also providing transient testing capabilities. The next largest American commercial facility is the General Electric, Cincinnati, test cells #43 and #44 with a capacity of 1000 lb/sec, which, although not meeting the 1200 lb/sec criteria, are used extensively for testing large turbofan military engines.

Large Turbojet, Small High-Bypass and Low-Bypass Turbofan Engines (Group 2)

Table 3b lists those facilities capable of testing these medium flow, high-speed engines (⩾480 lb/sec, M⩾3). The premier capability in the Western World is at AEDC with its ETF-T1, T2, T4, J1, and J2, in addition to its ASTF complex. All these provide large flows of heated and refrigerated air that offer good simulation of engine conditions over a wide operating range. Substantial capabilities also exist at other U.S. Government agencies (NAPC and NASA-Lewis) and U.S. industry (P & W and GE). Outside the United States, France (CEPr) has very good capability at the high flows over a wide Mach number range. The United Kingdom has reasonable airflow/Mach number capability, with the added advantage of transient testing abilities.

Medium and/or Small Turbojet Engines (Group 3)

As illustrated in Table 3c, the test facilities in this category are evenly distributed throughout the Western World in both industry and government agencies.

## Freejet Capabilities (Group 4)

Table 3d lists the freejet test facilities/capabilities identified in this survey. Many of these represent an additional capability to test facilities already listed under the previous categories, but are repeated with the dedicated freejet facilities for purposes of completeness. With the addition of a freejet capability at AEDC's ASTF-C2 in 1987, the United States will have the free world's premier facility for this type of engine testing. Excellent facilities also exist at the Marquardt Company in Van Nuys, California. The European capability is evenly distributed between the British and the French.

TABLE IIIa

ALTITUDE ENGINE TEST FACILITIES*

SUITABLE FOR TESTING LARGE BYPASS TURBOFAN ENGINES

Group 1

| Page No. | Facility/Cell Designation | Air Supply | | | Mach No. | Altitude (feet) | Physical Size (feet) | Thrust Stand (lbf) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | | Flow (PPS) | Temp ($^{o}$F) | Pressure (PSIA) | | | | | |
| 64 | AEDC, ASTF-C2 | 2760 | -100 +650 | Atmos. | 3.0 | 100 000 | 28 D x 85 L | 75 000 | Transient Testing |
| 63 | AEDC, ASTF-C1 | 1460 | -100 +1020 | 40 | 3.8 | 100 000 | 28 D x 85 L | 75 000 | Transient Testing |
| 62 | AEDC, ETF-J2 | 1400 | -10 +750 | 35 | 3.2 | 80 000 | 20 D x 103 L | 70 000 | |
| 61 | AEDC, ETF-J1 | 1400 | -15 +750 | 13 | 3.2 | 80 000 | 16 D x 72 L | 50 000 | |
| 15 | RAE (PYE), 3W | 1390 | -35 Ambient | Atmos. | 1.0 | 59 000 | 25 D x 56 L | 50 000 | Icing |
| 83 | P&W-AW, X218 | 1200 | -10 +90 | 12.5 | 1.0 | 40 000 | 24 D x 45 L | 100 000 | Transient Testing |
| 82 | P&W-AW, X217 | 1200 | -10 +90 | 12.5 | 1.0 | 40 000 | 18 D x 35 L | 50 000 | |

*Table shows limit of capabilities only.

TABLE IIIb

ALTITUDE ENGINE TEST FACILITIES*

SUITABLE FOR TESTING LARGE TURBOJET, SMALL HIGH-BYPASS TURBOFANS, AND LOW-BYPASS TURBOFANS

Group 2

| Page No. | Facility/Cell Designation | Air Supply Flow (PPS) | Air Supply Temp (°F) | Air Supply Pressure (PSIA) | Altitude (feet) | Mach No. | Physical Size (feet) | Thrust Measurement (lbf) | Full Transient Capability |
|---|---|---|---|---|---|---|---|---|---|
| 64 | AEDC, C-2 | 1460 | -100 +650 | 50 | 100 000 | 3.0 | 28 D x 85 L | 75 000 | Yes |
| 63 | AEDC, C-1 | 1460 | -100 +1020 | 40 | 100 000 | 3.8 | 28 D x 85 L | 75 000 | Yes |
| 62 | AEDC, J-2 | 1400 | -10 +750 | 35 | 80 000 | 3.2 | 20 D x 103 L | 70 000 | No |
| 77 | GE, TC-43** | 1000 | AMB +650 | 43 | 60 000 | 1 - 3.0 | 12 D x 56 L | Yes | No |
| 77 | GE, TC-44** | 1000 | AMB +650 | 43 | 60 000 | 1 - 3.0 | 17 D x 56 L | Yes | No |
| — | GE, TC-45** | 1000 | AMB +650 | 43 | 60 000 | 1 - 3.0 | 17 D x 56 L | Yes | No |
| 89 | CEPr, R-5 | 825 | (Refrig.) +1200 | 100 | 66 000 | 4.0 | 18 D x 100 L | 67 000 | No |

*Table shows limit of capabilities only.

**Minimum subsonic test capability (no refrigerated air).

TABLE IIIb (Continued)

| Page No. | Facility/Cell Designation | Air Supply Flow (PPS) | Air Supply Temp (°F) | Air Supply Pressure (PSIA) | Altitude (feet) | Mach No. | Physical Size (feet) | Thrust Measurement (lbf) | Full Transient Capability |
|---|---|---|---|---|---|---|---|---|---|
| 56 | AEDC, T-1 | 800 | -120 +650 | 35 | 80 000 | 3.0 | 12.3 D x 75 L | 30 000 | No |
| 57 | AEDC, T-2 | 800 | -120 +650 | 35 | 80 000 | 3.0 | 12.3 D x 68 L | 30 000 | No |
| 58 | AEDC, T-4 | 800 | -120 +650 | 35 | 80 000 | 3.0 | 12.3 D x 55 L | 30 000 | No |
| 61 | AEDC, J-1 | 700 | -65 +750 | 40 | 80 000 | 3.2 | 16 D x 72 L | 50 000 | No |
| 68 | NAPC, 3E | 700 | -65 +650 | 30 | 80 000 | 3.0 | 17 D x 30 L | 50 000 | No |
| 94 | RAE (PYE), ATF-3 | 600 | -100 +872 | 29 | 62 000 | 3.5 | 20 D x 80 L | 50 000 | Yes |
| 85 | P&WA, X-208 | 580 | -20 +625 | 45 | 80 000 | 3.0 | 12 D x 34 L | 25 000 | No |
| 54 | NASA LeRC, PSL-3 | 480 | -50 +600 | 60 | 80 000 | 3.0 | 24 D x 38 L | 40 000 | No |
| 55 | NASA LeRC, PSL-4 | 480 | -50 +1200 | 60 | 80 000 | 4.0 | 24 D x 38 L | 40 000 | No |

## TABLE IIIc

## ALTITUDE ENGINE TEST FACILITIES*

## SUITABLE FOR TESTING MEDIUM OR SMALL TURBOJET ENGINES

Group 3

| Page No. | Facility/Cell Designation | Air Supply Flow (PPS) | Air Supply Temp (°F) | Air Supply Pressure (PSIA) | Mach No. | Altitude (feet) | Physical Size (feet) | Thrust Stand (lbf) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 79 | GE, TC-40 | 450 | -100 +400 | 60 | 2.5 | 600 | 20 x 20 x 60 L | | |
| 88 | CEPr, R-3 | 441 | -85 +390 | 30 | 2.4 | 65 000 | 11.5 D x 60 L | 45 000 | |
| 88 | CEPr R-4 | 441 | -85 +390 | 30 | 2.4 | 65 600 | 11.5 D x 60 L | 45 000 | |
| 66 | NAPC, 1E | 430 | -65 +320 | 30 | 3.0 | 80 000 | 14 D x 18 L | | Icing |
| 65 | NAPC, 2E | 430 | -65 +320 | 30 | 3.0 | 80 000 | 14 D x 18 L | | Icing |
| 75 | Allison, 881 | 420 | -40 +210 | 26.5 | 1.0 | 50 000 | 18 D x 65 L | 30 000 | |
| 98 | RR (DE), ATF-1 | 400 | -113 +355 | 73 | 2.5 | 70 000 | 9 D x 38 L | 20 200 | |
| 99 | RR (DE), ATF-2 | 400 | -113 +355 | 73 | 2.5 | 70 000 | 9 D x 38 L | 20 200 | |
| 60 | AEDC, ETF-T6 | 375 | -30 +300 | 70 | 3.0 | 90 000 | 3 D x 18 L | | Plume Studies |
| 90 | CEPr, S1 | 221 | – +661 | 29 | 3.5 | 62 000 | 20 D x 80 L | 50 000 | Icing |

*Table shows limit of capabilities only.

TABLE IIIc (Continued)

| Page No. | Facility/Cell Designation | Air Supply Flow (PPS) | Air Supply Temp (°F) | Air Supply Pressure (PSIA) | Mach No. | Altitude (feet) | Physical Size (feet) | Thrust Stand (lbf) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 86 | P&W,<br>209 | 200 | -20<br>+650 | 12.5 | 3.0 | 80 000 | 12 D x 34 L | 25 000 | |
| 78 | GE,<br>TC-A1 | 175 | -70<br>+100 | 100 | 2.5 | 85 000 | 7 x 8 x 16.5 L | | |
| 91 | US-ILA,<br>HPT | 154 | -100<br>+350 | 28 | 2.2 | 65 600 | 10 D x 33 L | 22 500 | |
| 89 | CEPr,<br>C1 | 121 | -86<br>+175 | 17 | 1.0 | 36 000 | 11 D x 26 L | 2250 | |
| 72 | Allison,<br>871 | 120 | -75<br>+160 | 30 | 1.7 | 50 000 | | | Turboshaft<br>15 000 HA |
| 73 | Allison,<br>872 | 120 | -75<br>+160 | 30 | 1.7 | 50 000 | | | Turboshaft<br>8000 HA |
| 74 | Allison,<br>873 | 120 | -75<br>+160 | 80 | 1.7 | 45 000 | 14 D x 40 L | | Turboshaft<br>10 000 HA |
| 59 | AEDC,<br>ETF-T5 | 50 | -65<br>+650 | 40 | 3.0 | 80 000 | 7 D x 17 L | 5000 | |
| 87 | NRC,<br>Alt. Tst. Ch. | 12 | -70<br>+212 | 160 | 0.7 | 45 000 | 7 D x 12 L | | |
| 92 | Mitsubishi,<br>1007 | 12 | -50<br>+180 | 33 | 1.2 | 20 000 | 8 D x 40 L | | |
| 76 | Allison,<br>885 | 10 | -75<br>+160 | 30 | 1.0 | 25 000 | | | Turboshaft<br>800 HP |

TABLE IIId

ALTITUDE ENGINE TEST FACILITIES*

WITH FREEJET TEST CAPABILITY

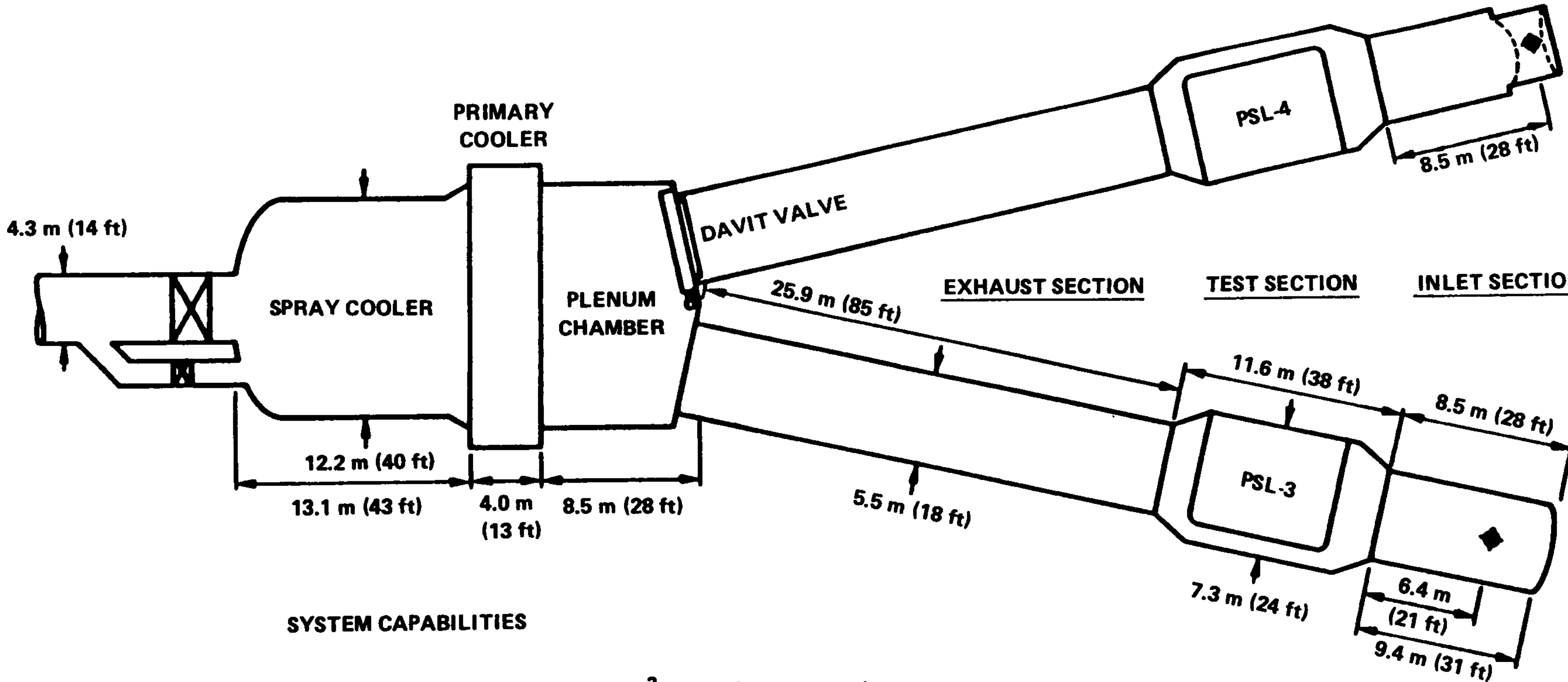
Group 4

| Page No. | Facility/Cell Designation | Air Supply Flow (PPS) | Air Supply Temp (°F) | Air Supply Pressure (PSIA) | Mach No. | Altitude (feet) | Physical Size (feet) | Thrust Stand (lbf) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 80 | MAR, TC-2 | 400 | – +5000 | 1500 | 8.0 | 110 000 | 12 D x 16 L | 100 000 | Blowdown |
| 81 | MAR, TC-8 | 1200 | – +5000 | 300 | 4.7 | 100 000 | 14 D x 80 L | 40 000 | Blowdown |
| 56 | AEDC, T-1 | 800 | -120 +650 | 35 | 3.0 | 80 000 | 12.3 D x 75 L | 30 000 | |
| 57 | AEDC, T-2 | 800 | -120 +650 | 35 | 3.0 | 80 000 | 12.3 D x 68 L | 30 000 | |
| 58 | AEDC, T-4 | 800 | -120 +650 | 35 | 3.0 | 80 000 | 12.3 D x 55 L | 30 000 | |
| 64 | AEDC, C2 | 1460 | -100 +650 | 50 | 3.0 | 100 000 | 28 D x 85 L | 75 000 | Freejet 1987 Transient Capa. |
| 95 | RAE (PYE), ATF-4 | 595 | Amb. +872 | 44 | 3.5 | 100 000 | 30 D x 69 L | 0 | No Direct Connect |
| 97 | RAE (PYE), ATF-1 | 400 | Amb. +422 | 132 | 3.5 | 100 000 | 12 D x 122 L | 0 | No Direct Connect |
| 98 | RR (BR), TP-131A | 400 | – +841 | 165 | 4.2 | 90 000 | 10 D x 80 L | 0 | Blowdown |

*Table shows limit of capabilities only.

TABLE IIId (Continued)

| Page No. | Facility/Cell Designation | Air Supply Flow (PPS) | Air Supply Temp (°F) | Air Supply Pressure (PSIA) | Mach No. | Altitude (feet) | Physical Size (feet) | Thrust Stand (lbf) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 98 | RR (DE), ATF-1 | 400 | -113 +355 | 73 | 2.5 | 70 000 | 9 D x 38 L | 20 200 | |
| 99 | RR (DE), ATF-2 | 400 | -113 +355 | 73 | 2.5 | 70 000 | 9 D x 38 L | 20 000 | |
| 89 | CEPr, R-5 | 825 | – +1200 | 100 | 4.0 | 65 600 | 18 D x 100 L | 67 500 | |
| 88 | CEPr, R-3 | 441 | -85 +390 | 30 | 2.4 | 65 600 | 11.5 D x 60 L | 45 000 | |
| 88 | CEPr, R-4 | 441 | -85 +390 | 30 | 2.4 | 65 600 | 11.5 D x 60 L | 45 000 | |
| 91 | US-ILA, HPT | 154 | -100 +350 | 28 | 2.2 | 65 600 | 10 D x 33 L | 22 500 | Transient Capa. |
| 94 | RAE (PYE), ATF-3 | 600 | -100 +872 | 29 | 3.5 | 62 000 | 20 D x 80 L | 50 000 | Icing |
| 90 | CEPr, S1 | 221 | – +661 | 29 | 2.0 | 49 000 | 12 D x 51 L | 22 500 | |
| 89 | CEPr, C1 | 121 | -86 +175 | 17 | 1.0 | 36 000 | 11 D x 26 L | 2250 | |
| — | AEDC, APTU | 1900 | – +1540 | 300 | 3.0 | 80 000 | 16 D x 42 L | 50 000 | Blowdown |
| 96 | RAE (PYE), ATF-3W | 1390 | -35 Amb. | Atmos. | Sub. | 59 000 | 25 D x 56 L | 50 000 | |




SYSTEM CAPABILITIES

| | |
|---|---|
| MAXIMUM AIR FLOW | 218 kg/sec at 41 N/cm$^2$ (480 lb/sec at 60 psia) |
| INLET AIR TEMPERATURE RANGE | 228 to 589 K (−50° to 600° F/1200°F FOR PSL - 4 |
| ALTITUDE RANGE | 1525 to 21 335 m (5000 to 80 000 ft) |

# PSL-3 & 4 ALTITUDE TEST CHAMBERS
## PLAN VIEW

| NASA–Lewis Research Center, Cleveland, OH | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 24 dia x 38 L | **MASS FLOW:** **(lb/sec)** 480; Refrigerated: 110; 140 | NASA–LeRC: PSL-4<br>DOD–AEDC: T-1, T-2, T-4, J-1, J-2<br>DOD–NAPC: 3E<br>Marquardt: TC-2, TC-8, P&W: X-207, X-209, X-210, X-217 |
| | **DATE BUILT/UPGRADED:** 1972 | **ALTITUDE RANGE:** **(ft)** 5 000 – 80 000 | |
| Propulsion Systems Laboratory (PSL-3) | **REPLACEMENT COST:** $60M | **TEMPERATURE RANGE:** **(°F)** –50° to +600° | |
| | **OPERATIONAL STATUS:** Two shifts per day | **PRESSURE RANGE:** **(psia)** 60; Refrigerated: 15; 25 | |
| | | **SPEED RANGE:** **(Mach No.)** 0 – 3 | |
| | Capacity of installed thrust stand: ±40 000 (lb/f)<br>Turbojets, turbofans, ramjets, and rockets | | Group 2 |

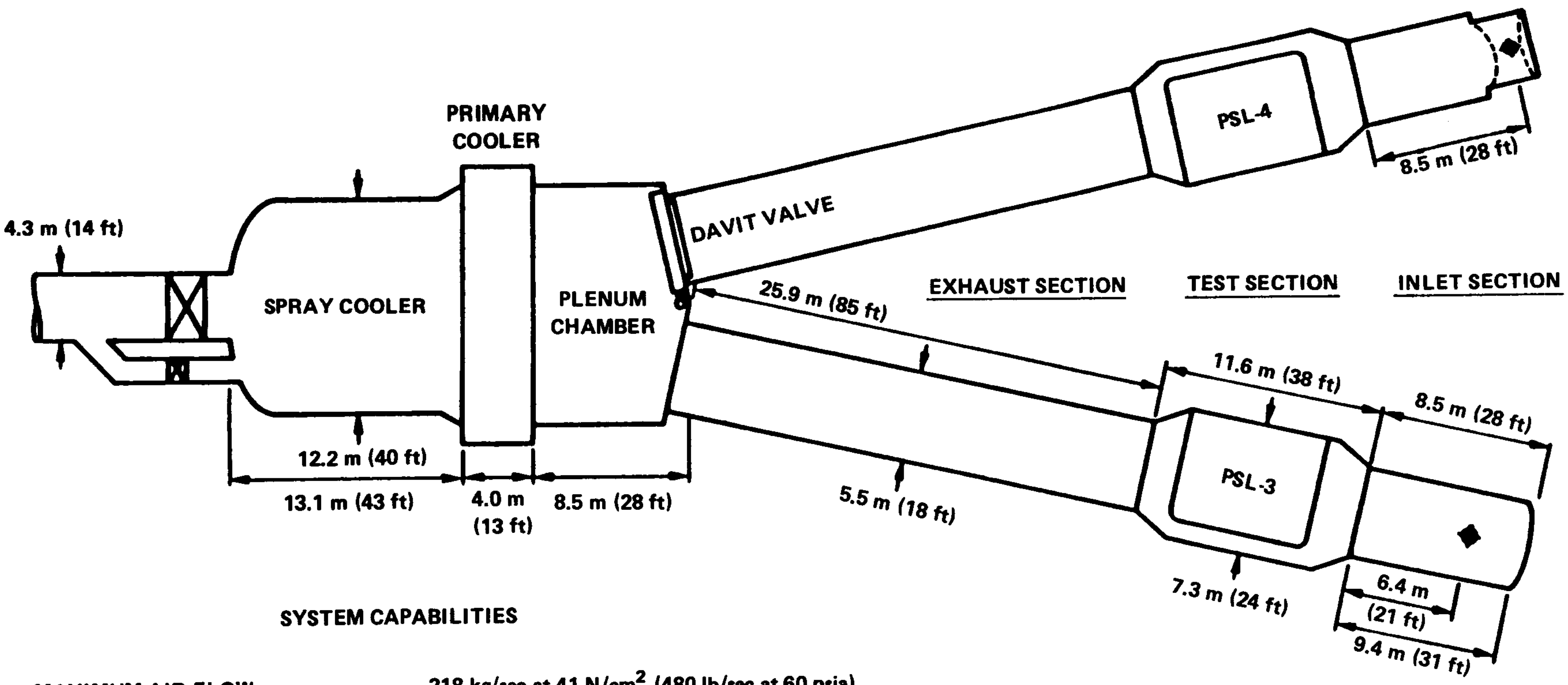
TESTING CAPABILITIES: PSL-3 provides the capability to test full-scale engines in a direct connect mode. Systems integration research, along with components research, is conducted in this facility. The facility is presently unique in its capability to test vectored exhaust nozzles at altitude conditions.

DATA ACQUISITION: Steady-state data system measures 512 pressure channels, 480 temperature channels, 256 analog inputs, and 16 frequency channels. Includes four real-time CRT graphics displays, analog recorders, indicators, motion picture, television systems, and three IR systems. Two transient data recording systems (195 channels each) and a system for onsite measurement and analysis of high frequency signals.

CURRENT PROGRAMS: Research studying advanced engine stability, control systems, exhaust nozzles, afterburners, and overall performance.

PLANNED IMPROVEMENTS: Complete the installation of a new steady-state computer system and pressure measurement system upgrade exhaust collection system, and enhance the engine buildup area. Raise inlet temperature limits to 2900°F, speed range to Mach 6, and altitude range to 144 000 ft for hypersonic test capabilities in FY 86 and FY 87.

LOCAL INFORMATION CONTACT: H. Bruce Block, PSL Operations, MS: 500-208, (216) 433-4000, ext. 442.




SYSTEM CAPABILITIES

| | |
|---|---|
| MAXIMUM AIR FLOW | 218 kg/sec at 41 N/cm$^2$ (480 lb/sec at 60 psia) |
| INLET AIR TEMPERATURE RANGE | 228 to 589 K (−50° to 600° F/1200°F FOR PSL - 4 |
| ALTITUDE RANGE | 1525 to 21 335 m (5000 to 80 000 ft) |

# PSL-3 & 4 ALTITUDE TEST CHAMBERS
## PLAN VIEW

| NASA–Lewis Research Center, Cleveland, OH | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** (ft) 24 dia x 38 L | **MASS FLOW:** 480 (lb/sec) Refrigerated: 110; 400 | NASA–LeRC: PSL-3<br>DOD–AEDC: T-1, T-2, T-4, J-1, J-2<br>DOD–NAPC: 3E<br>Marquardt: TC-2, TC-8<br>P&W: X-207, X-209, X-210, X-217 |
| | **DATE BUILT/UPGRADED:** 1972 | **ALTITUDE RANGE:** (ft) 5 000 – 80 000 | |
| Propulsion Systems Laboratory (PSL-4) | **REPLACEMENT COST:** $60M | **TEMPERATURE RANGE:** (°F) −50 to +600; +1200 | |
| | **OPERATIONAL STATUS:** Two shifts per day | **PRESSURE RANGE:** 60; 165 (psia) Refrigerated: 15; 25 | |
| | | **SPEED RANGE:** (Mach No.) 0 – 3 | |
| | Capacity of installed thrust stand: ±40 000 (lb/f)<br>Turbojets, turbofans, ramjets, and rockets | | Group 2 |

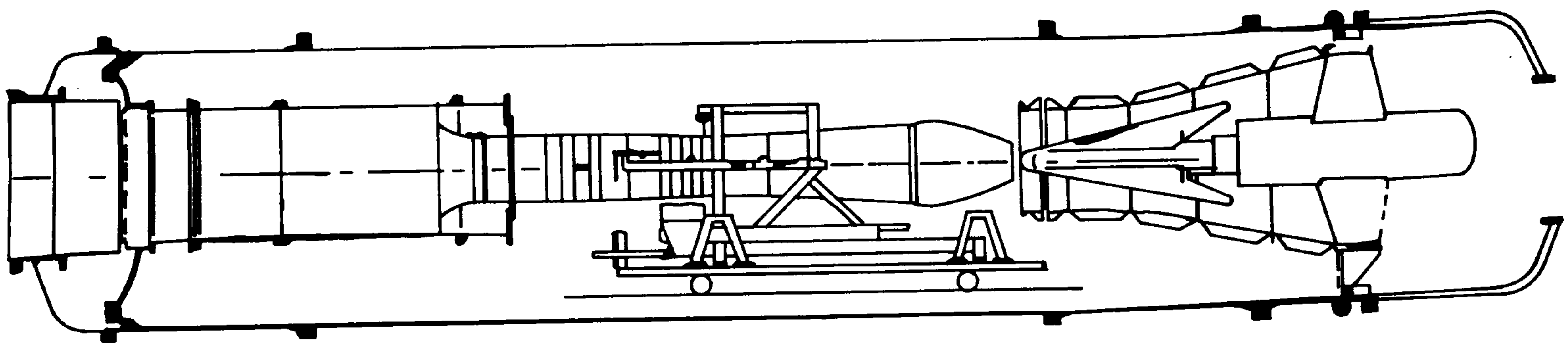
TESTING CAPABILITIES: PSL-4 provides the capability to test full-scale engines in a direct connect mode. Systems integration research, along with components research, is conducted in this facility. The facility is capable of providing inlet air up to 1660°R at 165 psia and 280 lbm/sec.

DATA ACQUISITION: Steady-state data system measures 512 pressure channels, 480 temperature channels, 256 analog inputs, and 16 frequency channels. Includes four real-time CRT graphics displays, analog recorders, indicators, motion picture, television systems, and three IR systems. Two transient data recording systems (195 channels each) and a system for onsite measurement and analysis of high frequency signals.

CURRENT PROGRAMS: Research studying advanced engine stability, control systems, afterburners, advanced materials, and overall performance.

PLANNED IMPROVEMENTS: Install a new steady-state computer system, pressure measurement system, and exhaust collection system. Enhance the engine buildup area capabilities.

LOCAL INFORMATION CONTACT: H. Bruce Block, PSL Operations, MS: 500-208, (216) 433-4000, ext. 442.



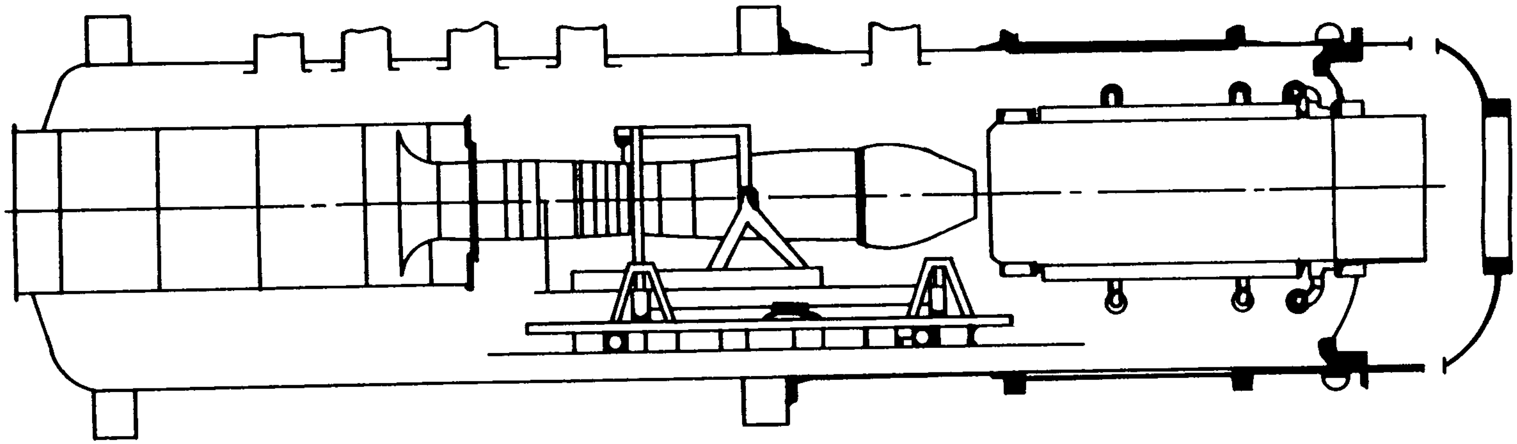
| DOD–Arnold Engineering Development Center, Tullahoma, TN | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** (ft) 12.3 dia x 35 to 75 L | **MASS FLOW:** (lb/sec) 450; 800 | DOD–AEDC: T-2, T-4, J-1, J-2<br>DOD–NAPC: 3E<br>NASA–LeRC: PSL-3, PSL-4<br>Marquardt: TC-2, TC-8<br>P&W–X-207, X-208, X-209, X-210, X-217 |
| | **DATE BUILT/UPGRADED:** 1954 | **ALTITUDE RANGE:** (ft) SL – 80 000 | |
| Propulsion Development Test Cell (T-1) | **REPLACEMENT COST:** $71M | **TEMPERATURE RANGE:** (°F) −120 to +650 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** (psia) 70; 35 | |
| | | **SPEED RANGE:** (Mach No.) Direct Connect: to 3.0; Freejet: 1.2, 1.6, 2.0, 3.0 | |
| | Capacity of installed thrust stand: ±30 000 (lb/f)<br>Turbojets, turbofans, and ramjets | | Groups 2, 4 |

TESTING CAPABILITIES: Direct-connect tests of air-breathing propulsion systems over a Mach number range from 0 to 3.0 can be accomplished. Freejet testing can be performed using available nozzles at subsonic Mach numbers and at Mach numbers of 1.2, 1.6, 2.0, and 3.0. A variable area ejector will soon provide near optimum exhaust pressure recovery over a wide range of operating conditions. The aft portion of the test cell and exhaust ducting is removable for installation of the test article.

DATA ACQUISITION: Computer-controlled data acquisition system (SEL 700) includes limited on-line and quick-look capability. Input channels: 300 aerodynamic pressure channels, 288 temperature channels, 192 high-speed general-purpose channels.

PLANNED IMPROVEMENTS: Test Installation Improvement Program and Variable Area Ejector.

LOCAL INFORMATION CONTACT: Major McTasney, Chief, Turbine Engine Division, AF/DOPT, (615) 455-2611, ext. 5305.



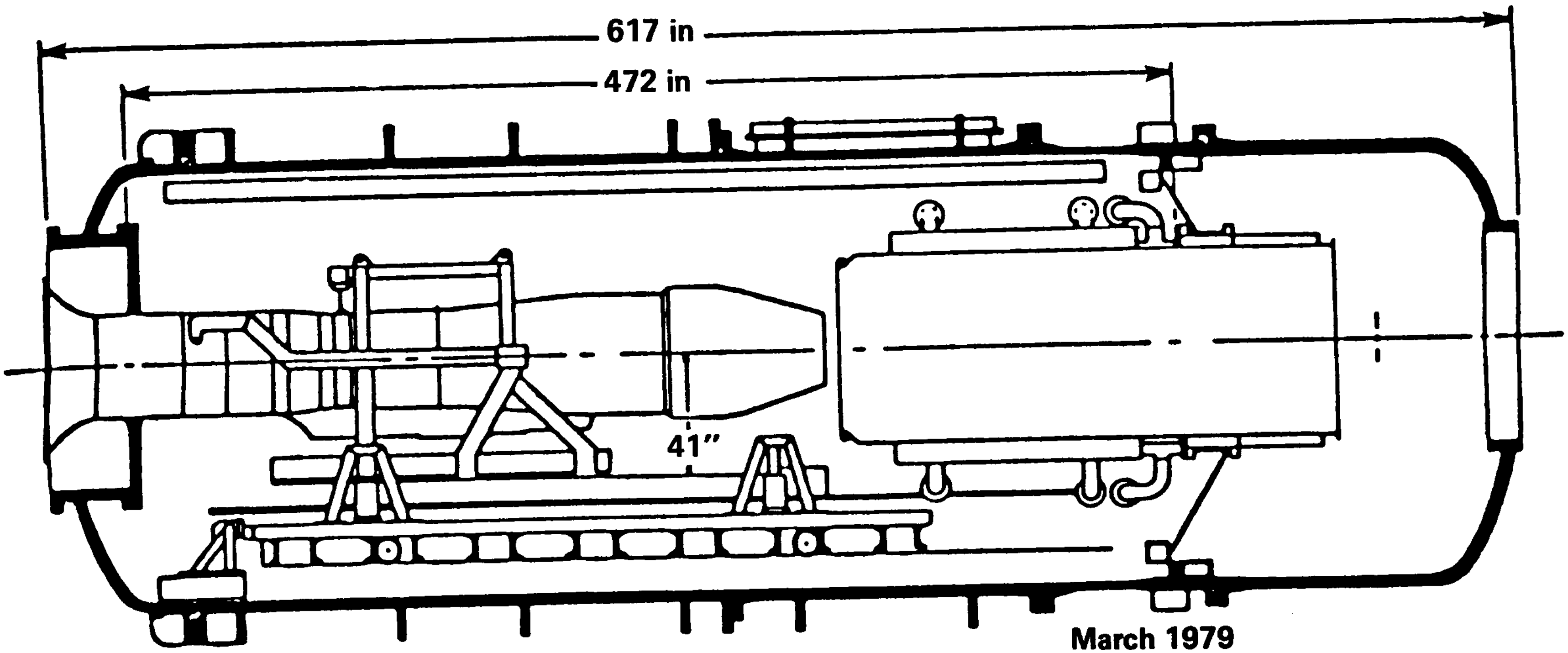
| DOD–Arnold Engineering Development Center, Tullahoma, TN | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 12.3 dia x 32 to 68 L | **MASS FLOW:** **(lb/sec)** 450; 800 | DOD–AEDC: T-1, T-4, J-1, J-2<br>NASA–LeRC: PSL-3, PSL-4<br>DOD–NAPC: 3E<br>Marquardt: TC-2, TC-8<br>P&W–X-207, X-208, X-209, X-210, X-217 |
| | **DATE BUILT/UPGRADED:** 1954 | **ALTITUDE RANGE:** **(ft)** SL – 80 000 | |
| Propulsion Development Test Cell (T-2) | **REPLACEMENT COST:** $72M | **TEMPERATURE RANGE:** **(°F)** –120 to +650 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** 70; 35 | |
| | | **SPEED RANGE:** **(Mach No.)** Direct Connect: to 3.0 Freejet: 1.2, 1.6, 2.0, 3.0 | |
| | Capacity of installed thrust stand: ±30 000 (lb/f)<br>Large turbojets and low-bypass turbofans<br>Freejet capability | | Groups 2, 4 |

TESTING CAPABILITIES: Direct-connect tests of air-breathing propulsion systems over a Mach number range from 0 to 3.0 can be accomplished. Freejet testing can be performed using available nozzles at subsonic Mach numbers and at Mach numbers of 1.2, 1.6, 2.0 and 3.0. The aft portion of the test cell and exhaust ducting is removable for installation of the test article.

DATA ACQUISITION: Computer-controlled data acquisition system (SEL 700) includes limited on-line and quick-look capability. Input channels: 300 aerodynamic pressure channels, 288 temperature channels, 192 high-speed general-purpose channels.

PLANNED IMPROVEMENTS: Test Installation Improvement Program.

LOCAL INFORMATION CONTACT: Major McTasney, Chief, Turbine Engine Division, AF/DOPT, (615) 455-2611, ext. 5305.




Elevation View

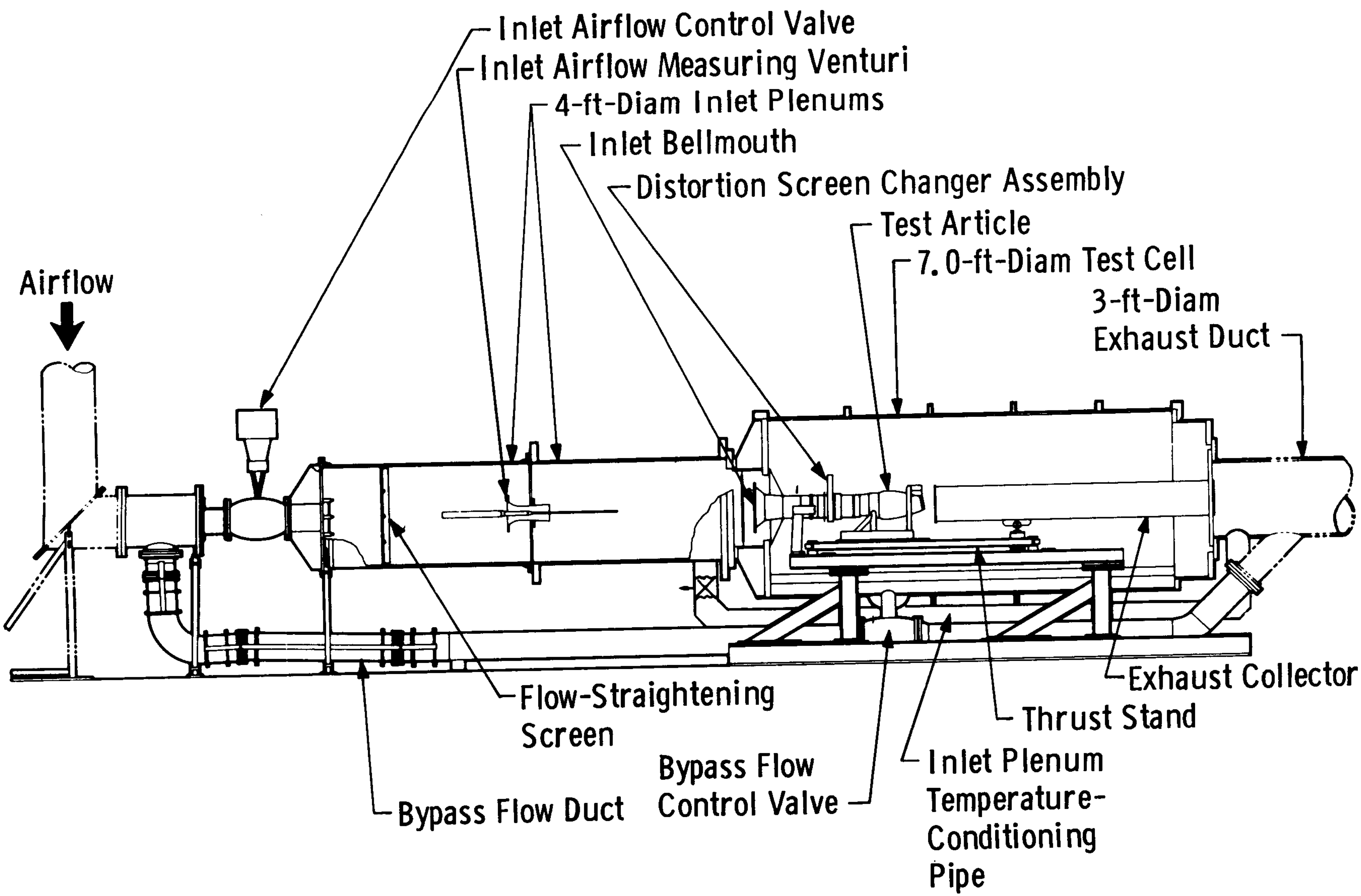
| Facility | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| DOD–Arnold Engineering Development Center, Tullahoma, TN | **TEST CHAMBER SIZE:** (ft) 12.3 dia x 19 to 55 L | **MASS FLOW:** (lb/sec) 450; 800 | DOD–AEDC: T-1, T-2, J-1, J-2<br>DOD–NAPC: 3E<br>NASA–LeRC: PSL-3, PSL-4<br>Marquardt: TC-2, TC-8<br>P&W: X-207, X-208, X-209, X-210, X-217 |
| | **DATE BUILT/UPGRADED:** 1954 | **ALTITUDE RANGE:** (ft) SL – 80 000 | |
| Propulsion Development Test Cell (T-4) | **REPLACEMENT COST:** \$80M | **TEMPERATURE RANGE:** (°F) −120 to +650 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** (psia) 70; 35 | |
| | | **SPEED RANGE:** (Mach No.) Direct Connect: to 3.0<br>Freejet: 1.2, 1.6, 2.0, 3.0 | |
| | Capacity of installed thrust stand: ±30 000 (lb/f)<br>Turbojets, turbofans, and ramjets | | Groups 2, 4 |

TESTING CAPABILITIES: Direct-connect tests of air-breathing propulsion systems over a Mach number range from 0 to 3.0 can be accomplished. Freejet testing can be performed using available nozzles at subsonic Mach numbers and at Mach numbers of 1.2, 1.6, 2.0, and 3.0. The aft portion of the test cell and exhaust ducting is removable for installation of the test article.

DATA ACQUISITION: Computer-controlled data acquisition system (SEL 700) includes limited on-line and quick-look capability. Input channels: 300 aerodynamic pressure channels, 288 temperature channels, 192 high-speed general-purpose channels.

PLANNED IMPROVEMENTS: Test Installation Improvement Program and Variable Area Ejector.

LOCAL INFORMATION CONTACT: Major McTasney, Chief, Turbine Engine Division, AF/DOPT, (615) 455-2611, ext. 5305.


Inlet Airflow Control Valve
Inlet Airflow Measuring Venturi
4-ft-Diam Inlet Plenums
Inlet Bellmouth
Distortion Screen Changer Assembly
Test Article
7.0-ft-Diam Test Cell
3-ft-Diam Exhaust Duct
Airflow
Exhaust Collector
Thrust Stand
Inlet Plenum Temperature-Conditioning Pipe
Bypass Flow Control Valve
Bypass Flow Duct
Flow-Straightening Screen

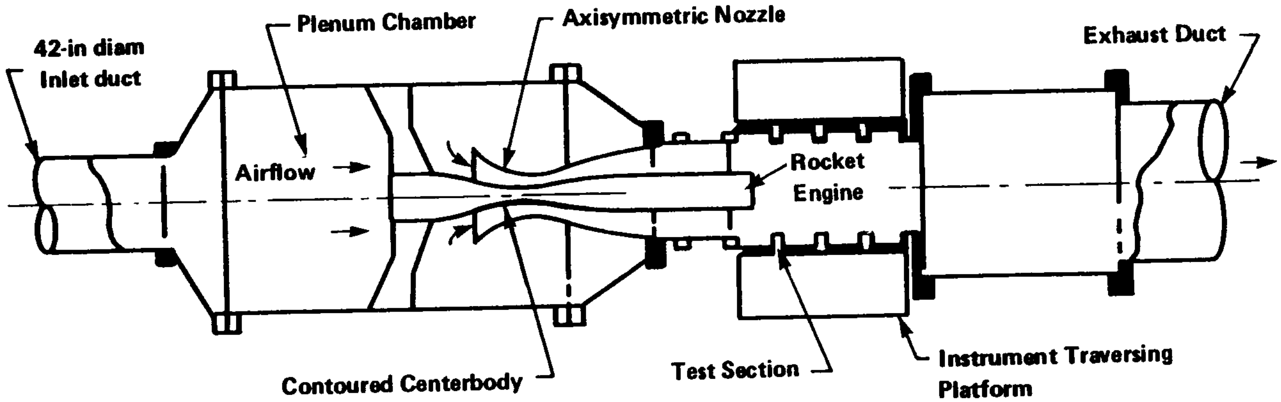
| DOD–Arnold Engineering Development Center, Tullahoma, TN | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE: (ft)** 7 dia x 17 L | **MASS FLOW: (lb/sec)** 50 | DOD–AEDC: T-1, T-2, T-4, T-6<br>Marquardt: TC-2, TC-8<br>DOD–NAPC: 1E, 2E, 3E<br>P&W: X-207, X-208, X-209, X-210, X-217 |
| | **DATE BUILT/UPGRADED:** 1954 | **ALTITUDE RANGE: (ft)** SL – 80 000 | |
| Propulsion Development Test Cell (T-5) | **REPLACEMENT COST:** $70M | **TEMPERATURE RANGE: (°F)** –50 to +650 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE: (psia)** 40 | |
| | | **SPEED RANGE: (Mach No.)** 0 – 3.0 | |
| | Capacity of installed thrust stand: ±5000 (lb/f)<br>Medium and small turbojets and ramjets | | Group 3 |

TESTING CAPABILITY: The test cell is designed for tests of small turbofan, turbojet, and ramjet engines. The cell is equipped with a 180° hatch over its full length and hinged at 45 degrees.

DATA ACQUISITION: Computer-controlled data acquisition system (SEL 700) includes limited on-line and quick-look capability. Input channels; 240 aerodynamic pressure channels, 192 temperature channels, 200 high-speed general-purpose channels.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Major McTasney, Chief, Turbine Engine Division, AF/DOPT, (615) 455-2611, ext. 5305.


42-in diam
Inlet duct
Plenum Chamber
Airflow
Axisymmetric Nozzle
Contoured Centerbody
Rocket
Engine
Test Section
Instrument Traversing
Platform
Exhaust Duct

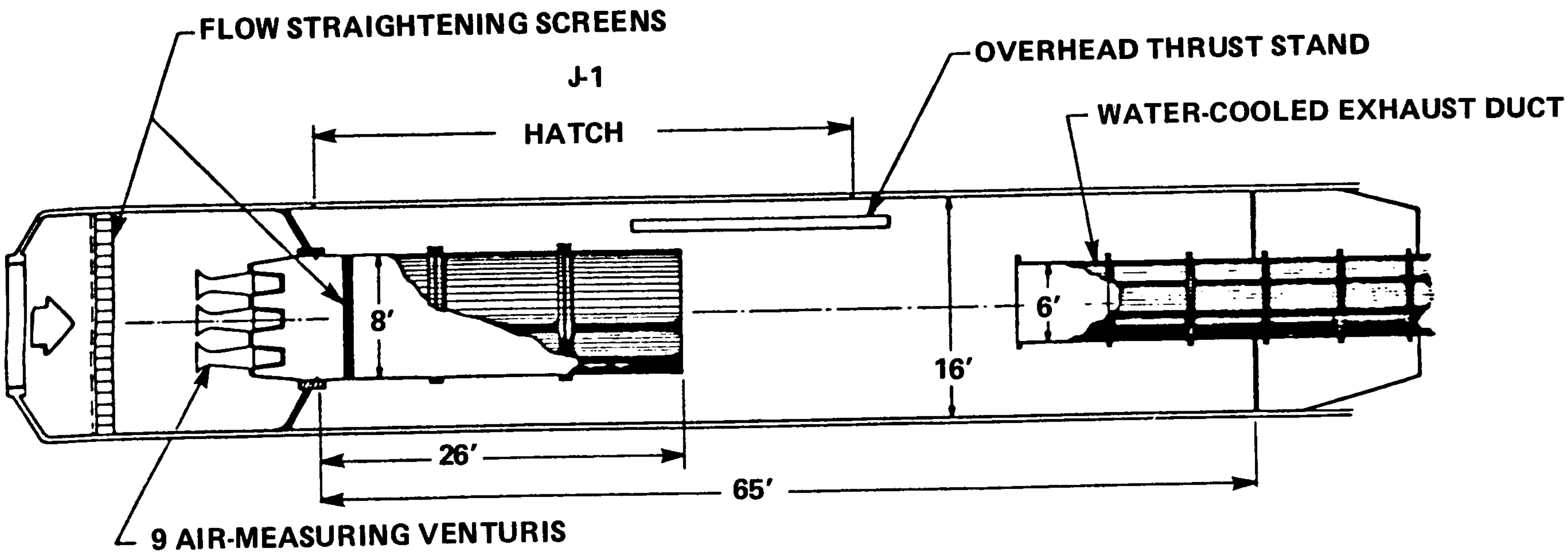
| DOD–Arnold Engineering Development Center, Tullahoma, TN | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 3 dia x 18 L | **MASS FLOW:** **(lb/sec)** 375 | None |
| | **DATE BUILT/UPGRADED:** 1955 | **ALTITUDE RANGE:** **(ft)** SL – 90 000 | |
| Propulsion Development Test Cell (T-6) | **REPLACEMENT COST:** $66M | **TEMPERATURE RANGE:** **(°F)** –30 to +300 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** 70 | |
| | | **SPEED RANGE:** **(Mach No.)** 0 – 3.0 | |
| | Capacity of installed thrust stand: None<br>Turbojet, turbofan, and ramjet<br>Combustion and emission measurements | | Group 3 |

TESTING CAPABILITIES: The cell consists of a 7-ft diameter inlet plenum chamber, a 3-ft diameter by 18-ft long test section, and an exhaust diffuser. Modifications have been made to provide a capability for measuring exhaust plume spectral characteristics of rocket engines in simulated flight environments from low subsonic Mach numbers to Mach number 3.0 at altitudes up to 90 000 ft.

DATA ACQUISITION: Computer-controlled data acquisition system (SEL) includes limited on-line and quick-look capability. Input channels: 100 aerodynamic pressure channels, 36 temperature channels, 192 high-speed general-purpose channels.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Major McTasney, Chief, Turbine Engine Division, AF/DOPT, (615) 455-2611, ext. 5305.


FLOW STRAIGHTENING SCREENS
J-1
HATCH
OVERHEAD THRUST STAND
WATER-COOLED EXHAUST DUCT
8'
6'
16'
26'
65'
9 AIR-MEASURING VENTURIS

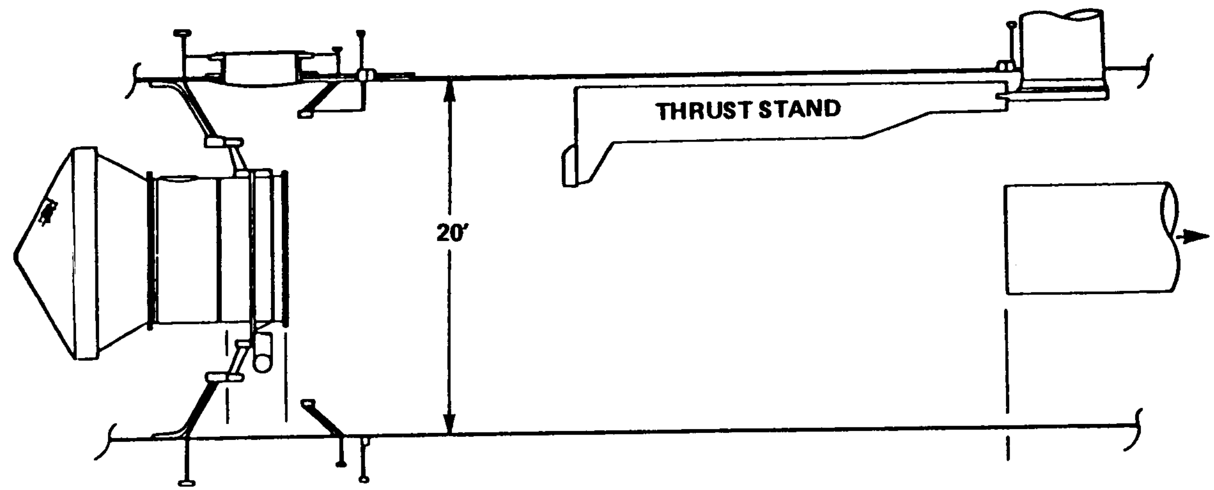
| DOD–Arnold Engineering Development Center, Tullahoma, TN | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 16 dia x 72 L | **MASS FLOW:** 500; 700; 1400 **(lb/sec)** Refrigerated: 1300 | DOD–AEDC: J-2, C-1, C-2<br>DOD–NAPC: 3E<br>Marquardt: TC-2, TC-8<br>P&W: X-217 |
| | **DATE BUILT/UPGRADED:** 1958 | **ALTITUDE RANGE:** **(ft x $10^{-3}$)** SL – 80 000 | |
| Propulsion Development Test Cell (J-1) | **REPLACEMENT COST:** $136M | **TEMPERATURE RANGE:** **(°F)** –65 to +750 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** 120; 40; 13 **(psia)** Refrigerated: 13 | |
| | | **SPEED RANGE:** **(Mach No.)** 0 – 3.2 | |
| | Capacity of installed thrust stands: ±50 000 (lb/f)<br>Large turbofans, turbojets, and ramjets | | Groups 1, 2 |

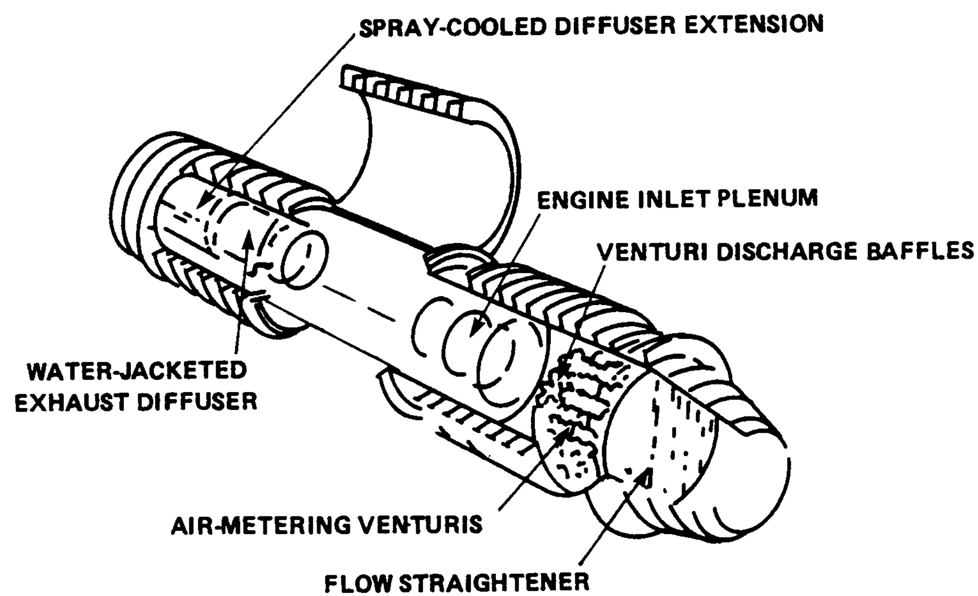
TESTING CAPABILITIES: J-1 is used primarily for performance and stability testing of large air-breathing propulsion systems. The test cell plenum is adapted so that air can be provided from either of two sources: one for heated air and the other for refrigerated air. The refrigerated air inlet can provide conditioned air at 395°R, which can be advantageous for icing investigations on inlets or engine components.

DATA ACQUISITION: Computer-controlled digital data acquisition system (SEL 800) includes two real-time CRT graphics display systems, analog recorders (magnetic tape, strip chart, oscillographs), indicators, and motion picture and television systems. Input channels: 600 aerodynamic pressure channels, 256 temperature channels, 132 low-speed general-purpose channels (200 samples/sec max), and 200 high-speed general-purpose channels (20 000 samples/sec max).

PLANNED IMPROVEMENTS: Install additional remote venturis.

LOCAL INFORMATION CONTACT: Major McTasney, Chief, Turbine Engine Division, AF/DOPT, (615) 455-2611, ext. 5305.


THRUST STAND
20'


SPRAY-COOLED DIFFUSER EXTENSION
ENGINE INLET PLENUM
VENTURI DISCHARGE BAFFLES
WATER-JACKETED
EXHAUST DIFFUSER
AIR-METERING VENTURIS
FLOW STRAIGHTENER

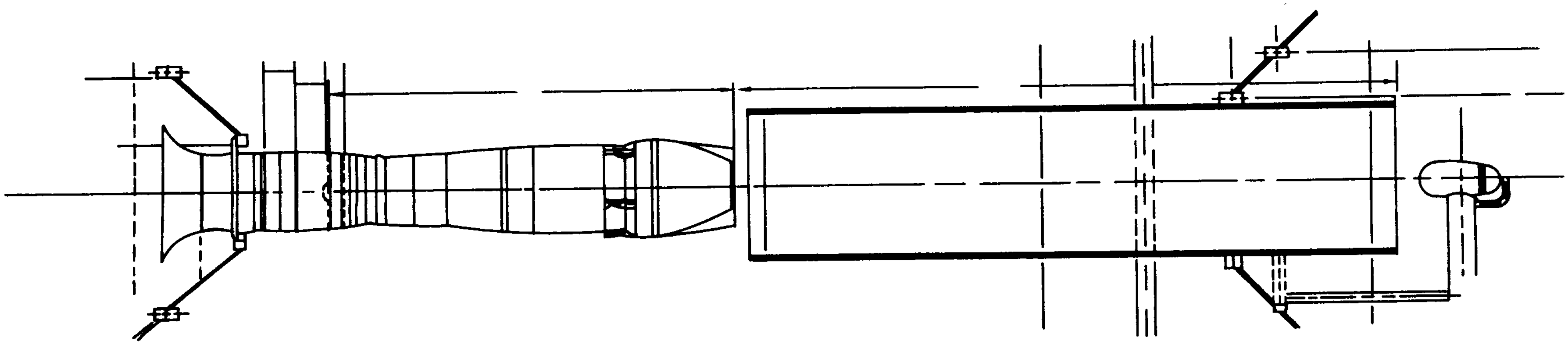
| DOD–Arnold Engineering Development Center, Tullahoma, TN | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 20 dia x 103 L | **MASS FLOW:** **(lb/sec)** 500; 700; 1400 | DOD–AEDC: C-1, C-2<br>Marquardt: TC-2, TC-8<br>P&W: X-217 |
| | **DATE BUILT/UPGRADED:** 1960 | **ALTITUDE RANGE:** **(ft)** SL – 80 000 | |
| Propulsion Development Test Cell (J-2) | **REPLACEMENT COST:** $148M | **TEMPERATURE RANGE:** **(°F)** −10 to +750 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** 120; 85; 35 | |
| | | **SPEED RANGE:** **(Mach No.)** 0 – 3.2 | |
| | Capacity of installed thrust stand: ±70 000 (lb/f)<br>Large turbofans, turbojets, and freejet capability | | Groups 1, 2 |

TESTING CAPABILITIES: J-2 is used primarily for performance and stability testing of large air-breathing propulsion systems. It has the basic capability for freejet testing of small air-breathing engines, such as cruise missiles. It also has the ability to investigate icing and anti-icing conditions.

DATA ACQUISITION: Computer-controlled digital data acquisition system (SEL 800) includes two real-time CRT graphics display systems, analog recorders (magnetic tape, strip chart, oscillographs), indicators, and motion picture and television systems. Input channels: 600 aerodynamic pressure channels, 344 temperature channels, 104 low-speed general-purpose channels (200 samples/sec max), and 200 high-speed general-purpose channels (20 000 samples/sec max).

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Major McTasney, Chief, Turbine Engine Division, AEDC/DOPT, (615) 455-2611, ext. 5305.



| DOD–Arnold Engineering Development Center, Tullahoma, TN | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 28 dia x 85 L | MASS FLOW: (lb/sec) 1100; 1460 | None |
| | DATE BUILT/UPGRADED: Under construction | ALTITUDE RANGE: (ft) 100 000 | |
| Propulsion Development Test Cell (ASTF C-1) | REPLACEMENT COST: $608M* | TEMPERATURE RANGE: (°F) −100 to +1020 | |
| | OPERATIONAL STATUS: Operational | PRESSURE RANGE: (psia) 130; 40 | |
| | | SPEED RANGE: (Mach No.) 0 – 3.8 | |
| | Capacity of installed thrust stand: ±75 000 (lb/f)<br>Large turbofans and turbojets | | Groups 1, 2 |

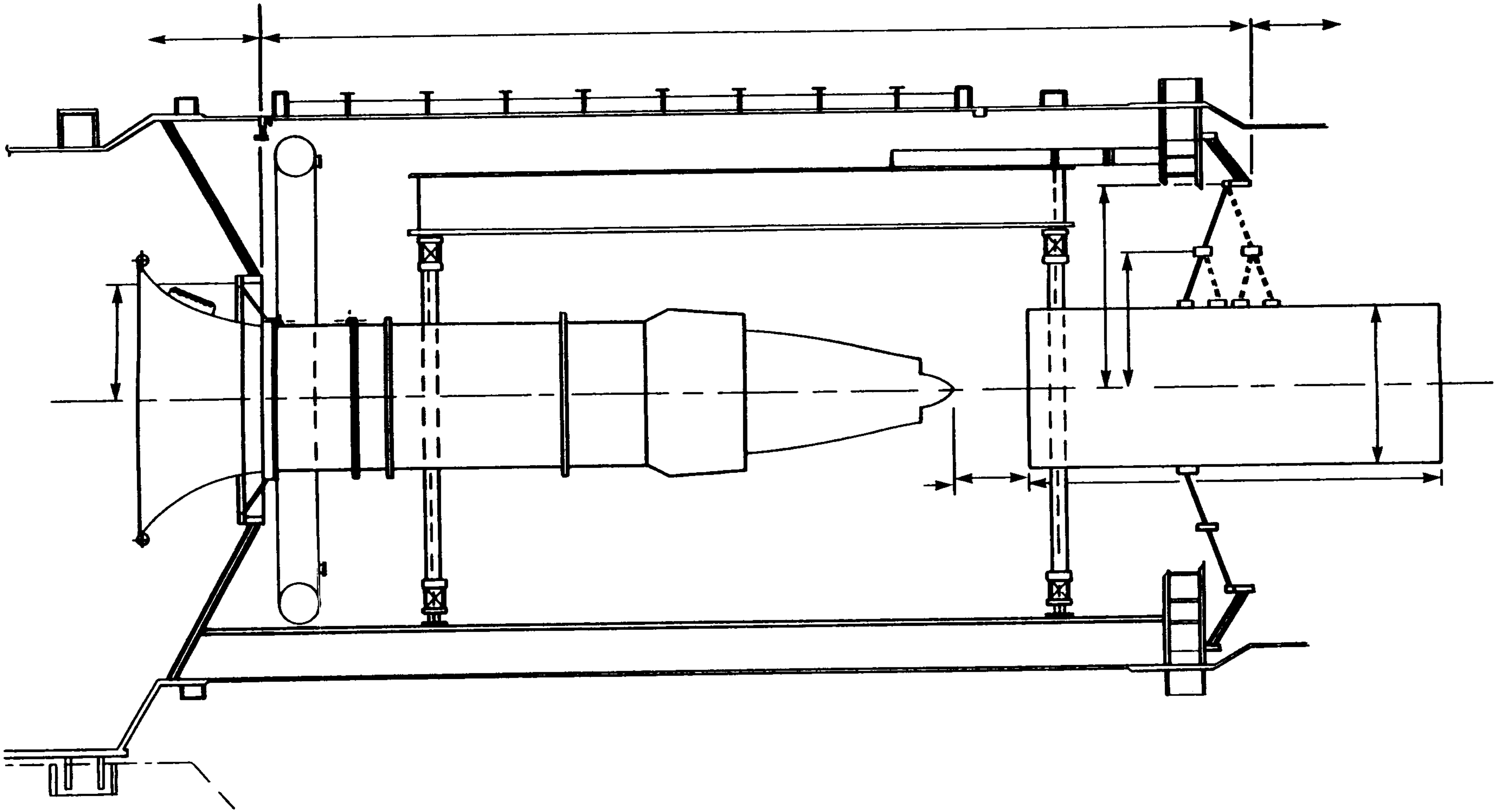
*Cost of test cell C-1, along with rest of ASTF facility except for test cell C-2. Facilities cost without C-1 and C-2 is $590 000 000.

TESTING CAPABILITIES: Cell C-1 is part of an open-circuit facility designed primarily for testing large air-breathing engine propulsion systems. The facility is designed to produce transient rate of change necessary to follow both flight environment and engine power transients. The potential exists to provide freejet capabilities at high Mach numbers using fixed nozzles (tentative).

DATA ACQUISITION: The data acquisition system, Test Instrumentation System (TIS), includes both the Mass Data Storage System and the Executive Data Processing System (EDPS). The EDPS accomplishes major performance calculations in real time with testing activities. An extensive interactive display system, with both alphanumeric and graphic terminals, is provided. Measuring Equipment: 1700 "static" measurement (typically <1 kHz) including 600 pneumatic multiplex, 1020 electronic multiplex; 226 "dynamic" measurement up to 20 kHz including 24 channels up to 50 kHz, 12 channels up to 100 kHz.

PLANNED IMPROVEMENTS: Develop exhaust collection and thrust measurement system to test engines with vectored and/or reverse thrust capability.

LOCAL INFORMATION CONTACT: Major McTasney, Chief, Turbine Engine Division, AF/DOPT, (615) 455-2611, ext. 5305.



| DOD–Arnold Engineering Development Center, Tullahoma, TN | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 28 dia x 85 L | **MASS FLOW:** **(lb/sec)** 1460; 2760 | None |
| | **DATE BUILT/UPGRADED:** Under construction | **ALTITUDE RANGE:** **(ft)** 100 000 | |
| Propulsion Development Test Cell (ASTF C-2) | **REPLACEMENT COST:** $608M* | **TEMPERATURE RANGE:** **(°F)** −100 to +650 | |
| | **OPERATIONAL STATUS:** Operational | **PRESSURE RANGE:** **(psia)** 50/Atm inbleed | |
| | | **SPEED RANGE:** **(Mach No.)** 0 – 3.0 | |
| | Capacity of installed thrust stand: ±75 000 (lb/f)<br>Large turbofans and turbojets | | Groups 1, 2, 4 |

*Cost of test cell C-2, along with rest of ASTF facility except for test cell C-1. Facilities cost without C-1 and C-2 is $590 000 000.

TESTING CAPABILITIES: Cell C-2 is part of an open-circuit facility designed primarily for testing large air-breathing engine propulsion systems in direct-connect and freejet modes. The facility is designed to produce transient rate of charge necessary to follow both flight environment and engine power transients. By late 1987, cell C-2 will be able to provide freejet capabilities at Mach numbers of 1.5, 2.0, and 2.5 through variable altitude nozzles of 48 $ft^2$ cross-section areas.

DATA ACQUISITION: The data acquisition system, Test Instrumentation System (TIS), includes both the Mass Data Storage System and the Executive Data Processing System (EDPS). EDPS accomplishes major performance calculations in real time with testing activities. An extensive interactive display system, with both alphanumeric and graphic terminals, is provided. Measuring Equipment: 1700 "shift" measurement (typically $<1$ kHz) including 600 pneumatic multiplex, 1020 electronic multiplex; 226 "dynamic" measurement up to 20 kHz including 24 channels up to 50 kHz, 12 channels up to 100 kHz.

PLANNED IMPROVEMENTS: Freejet Nozzle–operational in late 1987.

LOCAL INFORMATION CONTACT: Major McTasney, Chief, Turbine Engine Division, AF/DOPT, (615) 455-2611, ext. 5305.

| DOD–Naval Air Propulsion Center (NAPC), Trenton, NJ | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE: (ft)** 14.5 dia x 18 L | **MASS FLOW: (lb/sec)** 430 | NASA–LeRC: PSL-3, PSL-4<br>DOD–AEDC: T-1, T-2, T-4, J-1, J-2<br>FR–CEPr: R-3, R-4 |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE: (ft)** SL – 80 000 | |
| Cell 2E | **REPLACEMENT COST:** | **TEMPERATURE RANGE: (°F)** +390<br>Refrigerated: -65 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE: (psia)** 41 | |
| | | **SPEED RANGE: (Mach No.)** 2.4 | |
| | Capacity of installed thrust stand: ±30 000 (lb/f)<br>Direct connect, icing capability | | Group 3 |

TESTING CAPABILITIES: This facility has the following characteristics: ram air, fixed exhaust diffusers, refrigeration, exhaust gas cooler, heaters, vacuum exhausters, and quick-response inlet and exhaust control valves.

DATA ACQUISITION: Central on-line data acquisition and computation system with real-time output of test data on a control room CRT; also on-line tape data storage.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

| DOD–Naval Air Propulsion Center (NAPC), Trenton, NJ | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 14.5 dia x 18 L | MASS FLOW: (lb/sec) 430 | NASA–LeRC: PSL-3, PSL-4<br>DOD–AEDC: T-1, T-2, T-4, J-1, J-2<br>FR–CEPr: R-3, R-4 |
| | DATE BUILT/UPGRADED: | ALTITUDE RANGE: (ft) SL – 80 000 | |
| Cell 1E | REPLACEMENT COST: | TEMPERATURE RANGE: (°F) -65 to +390 | |
| | OPERATIONAL STATUS: | PRESSURE RANGE: (psia) 41 | |
| | | SPEED RANGE: (Mach No.) 0 – 2.4 | |
| | Capacity of installed thrust stand: ±30 000 (lb/f)<br>Direct connect, icing capability | | Group 3 |

TESTING CAPABILITIES: This facility has the following characteristics: ram air, fixed exhaust diffusers, refrigeration, exhaust gas cooler, heaters, vacuum exhausters, and quick-response inlet and exhaust control valves.

DATA ACQUISITION: Central on-line data acquisition and computation system with real-time output of test data on a control room CRT; also on-line tape data storage.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

| DOD–Naval Air Propulsion Center (NAPC), Trenton, NJ | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 8 x 8 x 15 L | MASS FLOW: (lb/sec) 100 | Allison: 871, 872, 873<br>FR–CEPr: C-1 |
| | DATE BUILT/UPGRADED: | ALTITUDE RANGE: (ft) 80 000 | |
| 3W | REPLACEMENT COST: | TEMPERATURE RANGE: (°F) +220<br>Refrigerated: -65 | |
| | OPERATIONAL STATUS: | PRESSURE RANGE: (psia) | |
| | | SPEED RANGE: (Mach No.) 1.1 | |
| | | | Group 1 |

TESTING CAPABILITIES: The Small Engine Test Area (SETA) contains four small altitude chambers (3W, 4W, 5W, and 6W) for testing small turbine engine accessories. In addition to simulating atmospheric test conditions, actual operational turboshaft engine loads can be simulated through the use of either dynamometer or water brake. A unique Center capability is the ability to separately test engine accessories such as turbine engine starters generators, pumps, etc. under simulated altitude and atmospheric conditions through the use of an external 300-hp drive system accessory.

DATA ACQUISITION: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

<table>
<tr><td rowspan="2">DOD–Naval<br>Air Propulsion<br>Center (NAPC)</td><th colspan="2">ALTITUDE ENGINE TEST FACILITIES</th><th>COMPARABLE FACILITIES</th></tr>
<tr><td>TEST CHAMBER SIZE:<br>(ft) 30 x 17</td><td>MASS FLOW:<br>(lb/sec) 700</td><td rowspan="6">NASA–LeRC:<br>PSL-3, PSL-4<br>DOD–AEDC:<br>T-1, T-2, T-4,<br>J-1, J-2<br>P&W: X-207, X-208,<br>X-209, X-210<br>U.K.–RAE(pye):<br>ATF C-3</td></tr>
<tr><td rowspan="6">Cell 3E</td><td>DATE BUILT/UPGRADED:</td><td>ALTITUDE RANGE:<br>(ft) 100 000</td></tr>
<tr><td>REPLACEMENT COST:</td><td>TEMPERATURE RANGE:<br>(°F) -65 to +650</td></tr>
<tr><td rowspan="2">OPERATIONAL STATUS:</td><td>PRESSURE RANGE:<br>(psia) 30</td></tr>
<tr><td>SPEED RANGE:<br>(Mach No.) 3.0</td></tr>
<tr><td colspan="2">Direct connect<br>Large turbojets and low-bypass turbofans</td></tr>
<tr><td colspan="2"></td><td>Group 2</td></tr>
</table>

TESTING CAPABILITIES: This altitude chamber can simulate conditions for evaluating the performance of the engine throughout the entire operating envelope. The facility has the following technical characteristics: ram air, variable exhaust diffusers, refrigeration, exhaust gas cooler, heaters, vacuum exhausters, quick-response inlet and exhaust control valves, and inlet system icing capability.

DATA ACQUISITION: Central on-line data acquisition and computation system with real-time output of test data on a control room CRT; also on-line tape data storage.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

| | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| DOD–Naval Air Propulsion Center (NAPC), Trenton, NJ | **TEST CHAMBER SIZE: (ft)** 10 dia x 20 L | **MASS FLOW: (lb/sec)** 100 | Allison: 871, 872, 873<br>FR–CEPr: C-1 |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE: (ft)** 80 000 | |
| 4W | **REPLACEMENT COST:** | **TEMPERATURE RANGE: (°F)** +220<br>Refrigerated: -65 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE: (psia)** | |
| | | **SPEED RANGE: (Mach No.)** 1.1 | |
| | | | Group 3 |

TESTING CAPABILITIES: The Small Engine Test Area (SETA) contains four small altitude chambers (3W, 4W, 5W, and 6W) for testing small turbine engine accessories. In addition to simulating atmospheric test conditions, actual operational turboshaft engine loads can be simulated through the use of either dynamometer or water brake. A unique Center capability is the ability to separately test engine accessories such as turbine engine starters generators, pumps, etc. under simulated altitude and atmospheric conditions through the use of an external 300-hp drive system accessory.

DATA ACQUISITION: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

| DOD–Naval Air Propulsion Center (NAPC), Trenton, NJ | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 10 x 10 x 17 L | **MASS FLOW:** **(lb/sec)** 100 | Allison: 871, 872, 873<br>FR–CEPr: C-1 |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE:** **(ft)** 80 000 | |
| 5W | **REPLACEMENT COST:** | **TEMPERATURE RANGE:** **(°F)** +220<br>Refrigerated: -65 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE:** **(psia)** | |
| | | **SPEED RANGE:** **(Mach No.)** 1.1 | |
| | | | Group 3 |

TESTING CAPABILITIES: The Small Engine Test Area (SETA) contains four small altitude chambers (3W, 4W, 5W, and 6W) for testing small turbine engine accessories. In addition to simulating atmospheric test conditions, actual operational turboshaft engine loads can be simulated through the use of either dynamometer or water brake. A unique Center capability is the ability to separately test engine accessories such as turbine engine starters generators, pumps, etc. under simulated altitude and atmospheric conditions through the use of an external 300-hp drive system accessory.

DATA ACQUISITION: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

| DOD–Naval Air Propulsion Center (NAPC), Trenton, NJ | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 10 x 10 x 17 L | **MASS FLOW:** **(lb/sec)** 100 | Allison: 871, 872, 873<br>FR–CEPr: C-1 |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE:** **(ft x $10^{-3}$)** 80 | |
| 6W | **REPLACEMENT COST:** | **TEMPERATURE RANGE:** **(°F)** +220<br>Refrigerated: -65 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE:** **(psia)** | |
| | | **SPEED RANGE:** **(Mach No.)** 1.1 | |
| | | | Group 3 |

TESTING CAPABILITIES: The Small Engine Test Area (SETA) contains four small altitude chambers (3W, 4W, 5W, and 6W) for testing small turbine engine accessories. In addition to simulating atmospheric test conditions, actual operational turboshaft engine loads can be simulated through the use of either dynamometer or water brake. A unique Center capability is the ability to separately test engine accessories such as turbine engine starters generators, pumps, etc. under simulated altitude and atmospheric conditions through the use of an external 300-hp drive system accessory.

DATA ACQUISITION: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

| | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| Allison Gas Turbine Operations, Indianapolis, IN | **TEST CHAMBER SIZE:** **(ft)** Not applicable | **MASS FLOW:** **(lb/sec)** 120 | DOD–NAPC: 3W, 4W, 5W, 6W<br>U.K.–Rolls Royce: ATF C-1 |
| | **DATE BUILT/UPGRADED:** 1958 | **ALTITUDE RANGE:** **(ft)** SL – 50 000 | |
| Cell 871 | **REPLACEMENT COST:** $9M | **TEMPERATURE RANGE:** **(°F)** –75 to +160 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** 2.2 – 30 | |
| | | **SPEED RANGE:** **(Mach No.)** 1.0 @ SL<br>1.7 @ 35 000 ft | |
| | Turboshaft engines to 15 000 hp @ 15 000 rpm<br>Medium and small turbojets | | Group 3 |

TESTING CAPABILITIES: Used for testing small generators (under 50 lb/sec) and free- and fixed-shaft turbine engines to 15 000 hp. Has motoring capability of 1000 hp. Primarily used for steady-state functional and performance testing. Direct-connect inlet and exhaust for altitude performance testing. No altitude transient capability.

DATA ACQUISITION: Shared central acquisition facility. Digital: IBM Series I and IBM 4331, with test-stand dedicated CRT and printer and DVM displays of on-line calculations. Off-line interactive graphics and high-speed batch printing. Up to 900 channels input in 50-channel blocks. Acquisition rate: 10 400 samples per second. Analog: Magnetic tape recorders, strip-chart recorders, oscillographs, and various indicators such as oscilloscope, bar graph, television, and FFT analyzers.

CURRENT PROGRAMS: Turboshaft.

PLANNED IMPROVEMENTS: Test unit safety monitor system, data acquisition system enhancements.

LOCAL INFORMATION CONTACT: W. R. Stiefel, Supervisor, Test Projects, (317) 242-3885.

| | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| Allison Gas Turbine Operations, Indianapolis, IN | **TEST CHAMBER SIZE:** **(ft)** Not applicable | **MASS FLOW:** **(lb/sec)** 120 | DOD–NAPC: 3W, 4W, 5W, 6W<br>U.K.–Rolls Royce: ATF C-1 |
| | **DATE BUILT/UPGRADED:** 1958 | **ALTITUDE RANGE:** **(ft)** SL – 50 000 | |
| Cell 872 | **REPLACEMENT COST:** $10M | **TEMPERATURE RANGE:** **(°F)** −75 to +160 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** 2.2 – 30 | |
| | | **SPEED RANGE:** **(Mach No.)** 1.0 @ SL<br>1.7 @ 35 000 ft | |
| | Turboshaft engines to 8000 hp @ 15 000 rpm<br>Medium and small turbojets | | Group 3 |

TESTING CAPABILITIES: Used for testing of small gas generators (under 50 lb/sec) and free- and fixed-shaft turbine engines to 8000 hp. Has motoring capability of 1000 hp. Primarily used for steady-state functional and performance testing. Direct-connect inlet and exhaust for altitude performance testing. No altitude transient capability.

DATA ACQUISITION: Shared central acquisition facility. Digital: IBM Series I and IBM 4331, with test-stand dedicated CRT and printer and DVM displays of on-line calculations. Off-line interactive graphics and high-speed batch printing. Up to 900 channels input in 50-channel blocks. Acquisition rate 10 400 samples per second. Analog: Magnetic tape recorders, strip-chart recorders, oscillographs, and various indicators such as oscilloscope, bar graph, television, and FFT analyzers.

CURRENT PROGRAMS: Turboshaft.

PLANNED IMPROVEMENTS: Upgrade power absorption capability, in 1984, to 15 000 hp; test unit safety monitor system; data acquisition system enhancements.

LOCAL INFORMATION CONTACT: W. R. Stiefel, Supervisor, Test Projects, (317) 242-3885.

| | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| Allison Gas Turbine Operations, Indianapolis, IN | **TEST CHAMBER SIZE: (ft)** 14 dia x 40 L | **MASS FLOW: (lb/sec)** 120 | DOD–NAPC: 3W, 4W, 5W, 6W<br>U.K.–Rolls Royce: ATF C-1<br>FR–CEPr: S-1, C-1 |
| | **DATE BUILT/UPGRADED:** 1958/1970 | **ALTITUDE RANGE: (ft)** SL – 45 000 | |
| Cell 873 | **REPLACEMENT COST:** $8M | **TEMPERATURE RANGE: (°F)** –75 to +160 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE: (psia)** 2.2 – 80 | |
| | | **SPEED RANGE: (Mach No.)** 1.0 @ SL<br>1.7 @ 35 000 ft | |
| | Turboshaft engines to 1000 hp @ 7500 rpm<br>Turboprop engines to 6000 hp @ 1600 rpm<br>Capable of engine starts/transients while maintaining altitude and RPR | | Group 3 |

TESTING CAPABILITIES: Used primarily for turboshaft and turboprop engine altitude performance and functional testing and environmental testing. Load absorbers available in 0 to 1000 hp and –250 to 6000 hp ranges. Usually operated in direct-connect mode but capable of freejet operation for small (less than 10 lb/sec) engines. Has icing simulation capability.

DATA ACQUISITION: Shared central acquisition facility. Digital: IBM Series I and IBM 4331, with test-stand dedicated CRT and printer and DVM displays of on-line calculations. Off-line interactive graphics and high-speed batch printing. Up to 900 channels input in 50-channel blocks. Acquisition rate 10 400 samples per second. Analog: Magnetic tape recorders, strip-chart recorders, oscillographs, and various indicators such as oscilloscope, bar graph, television, and FFT analyzers.

CURRENT PROGRAMS: Turboshaft, turboprop.

PLANNED IMPROVEMENTS: Test unit safety monitor, data acquisition system enhancements.

LOCAL INFORMATION CONTACT: W. R. Stiefel, Supervisor, Test Projects, (317) 242-3885.

| | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| Allison Gas Turbine Operations, Indianapolis, IN | **TEST CHAMBER SIZE:** **(ft)** 18 dia x 68 L | **MASS FLOW:** **(lb/sec)** 420 | DOD–AEDC: T-1, T-2, T-4, J-1, J-2<br>DOD–NAPC: 1E, 2E<br>NASA–LeRC: PSL-3, PSL-4 |
| | **DATE BUILT/UPGRADED:** 1954/1970 | **ALTITUDE RANGE:** **(ft)** SL – 50 000 | |
| Cell 881 | **REPLACEMENT COST:** $7M | **TEMPERATURE RANGE:** **(°F)** –40 to +210 | |
| | **OPERATIONAL STATUS:** Inactive/plan to dismantle exhauster system | **PRESSURE RANGE:** **(psia)** 1.7 – 26.5 | |
| | | **SPEED RANGE:** **(Mach No.)** 1.0 | |
| | Turbojet/turbofan engines to 30 000-lb thrust | | Group 3 |

TESTING CAPABILITIES: Turbofan engine sea-level/altitude performance, functional and environmental testing.

DATA ACQUISITION: Shared central acquisition facility. Digital: IBM Series I and IBM 4331, with test-stand dedicated CRT and printer and DVM displays of on-line calculations. Off-line interactive graphics and high-speed batch printing. Up to 900 channels input in 50-channel blocks. Acquisition rate 10 400 samples per second. Analog: Magnetic tape recorders, strip-chart recorders, oscillographs, and various indicators such as oscilloscope, bar graph, television, and FFT analyzers.

CURRENT PROGRAMS: None. Facility has been idle since 1971.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: W. R. Stiefel, Supervisor, Test Projects, (317) 242-3885.

| Allison Gas Turbine Operations, Indianapolis, IN | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) Not applicable | MASS FLOW: (lb/sec) 10 | Canada–NRC: Alt. Test Chamber |
| | DATE BUILT/UPGRADED: 1954/1972 | ALTITUDE RANGE: (ft) SL – 25 000 | |
| Cell 885 | REPLACEMENT COST: $4M | TEMPERATURE RANGE: (°F) –75 to +160 | |
| | OPERATIONAL STATUS: Active | PRESSURE RANGE: (psia) 5.5 – 30 | |
| | | SPEED RANGE: (Mach No.) 1.0 @ SL | |
| | Turboshaft engines to 800 hp, input speeds to 30 000 rpm | | Group 3 |

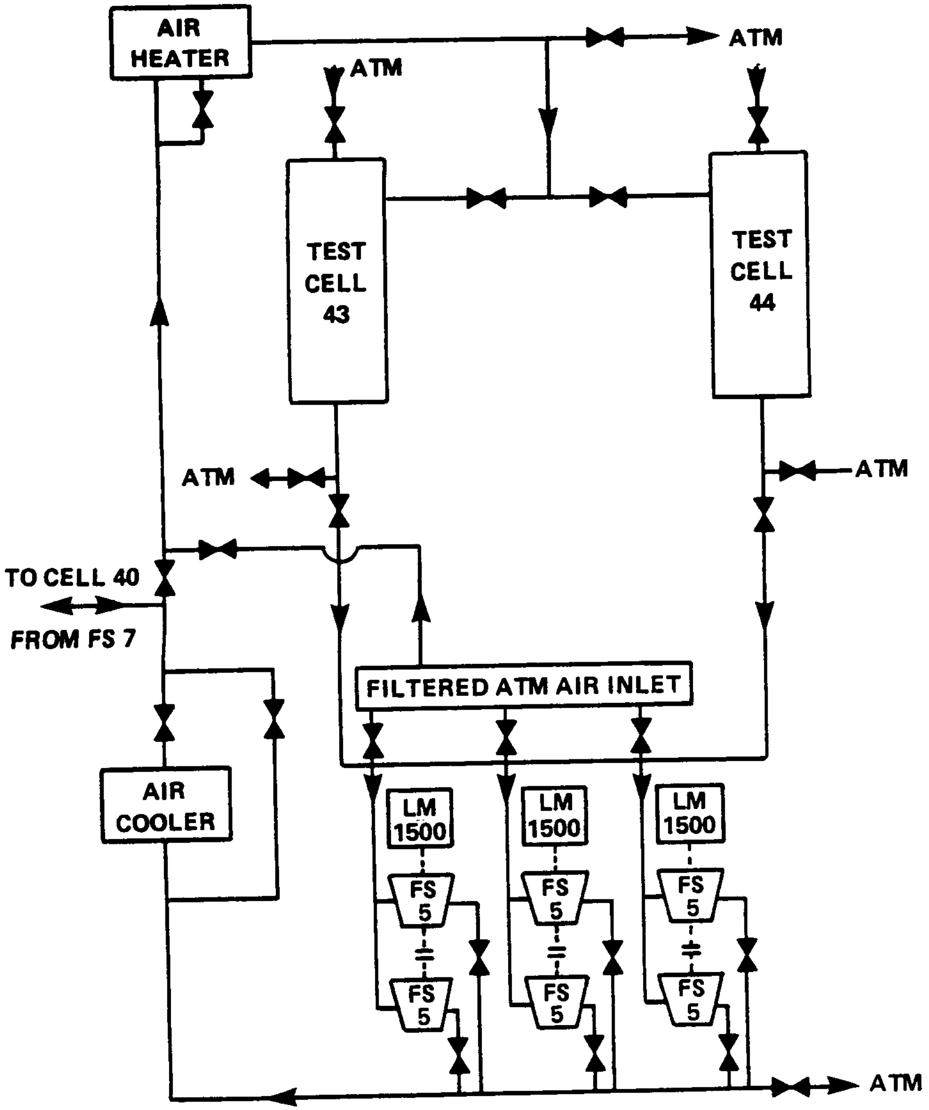
TESTING CAPABILITIES: Turboshaft engine sea-level/altitude performance, functional testing, small turbine rig testing. Direct-connect inlet and exhaust connections. No transient testing at altitude conditions.

DATA ACQUISITION: Shared central acquisition facility. Digital: IBM Series I and IBM 4331, with test-stand dedicated CRT and printer and DVM displays of on-line calculations. Off-line interactive graphics and high-speed batch printing. Up to 900 channels input in 50-channel blocks. Acquisition rate 10 400 samples per second. Analog: Magnetic tape recorders, strip-chart recorders, oscillographs, and various indicators such as oscilloscope, bar graph, television, and FFT analyzers.

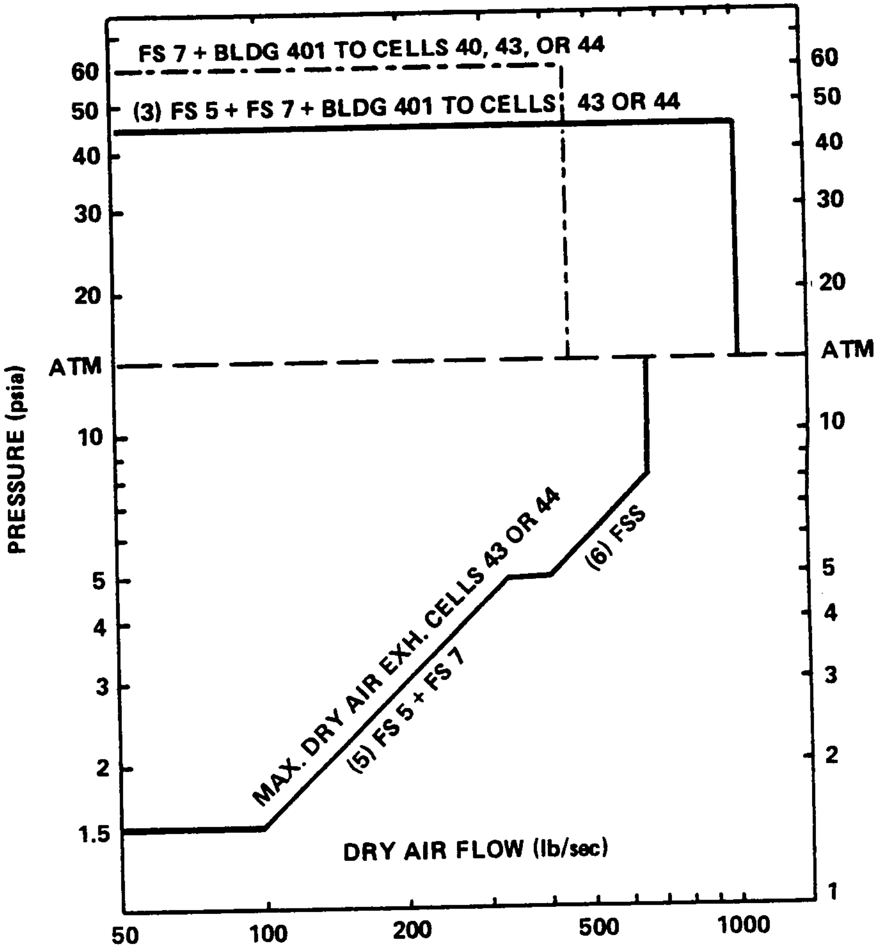
CURRENT PROGRAMS: Turboshaft engines, gas generators, turbines.

PLANNED IMPROVEMENTS: Test unit safety monitor system, data acquisition system enhancements.

LOCAL INFORMATION CONTACT: W. R. Stiefel, Supervisor, Test Projects, (317) 242-3885.




CELL 43/44 SCHEMATIC




CELL 40/43/44
PERFORMANCE CHART

| General Electric, Cincinnati, OH | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 17 dia x 56 L | MASS FLOW: (lb/sec) 450 – 1000 | DOD–AEDC: T-1, T-2, T-4, J-1, J-2, C-1, C-2 NASA–LeRC: PSL-3, PSL-4 U.K.–RAE (Pye): C-1, C-2, C-3 |
| | DATE BUILT/UPGRADED: 1968 | ALTITUDE RANGE: (ft) 60 000 | |
| TC 43 and TC 44 | REPLACEMENT COST: $20M | TEMPERATURE RANGE: (°F) +100 to +650 | |
| | OPERATIONAL STATUS: Active | PRESSURE RANGE: (psia) 60 – 43 | |
| | | SPEED RANGE: (Mach No.) 3.0 | |
| | Large turbojets and low bypass turbofans | | Group 2 |

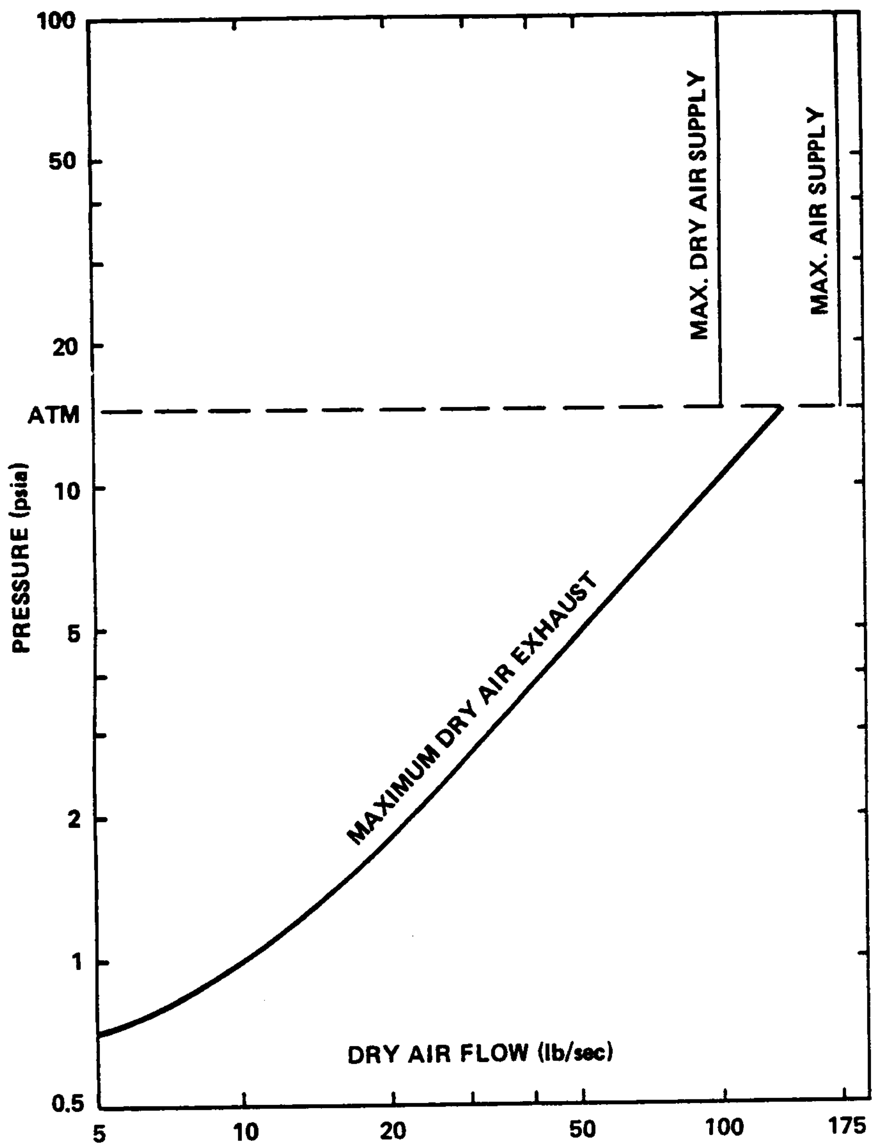
TESTING CAPABILITIES: Cells 43/44 used for performance endurance testing of large turbofan military engines at elevated inlet temperature and either elevated or vacuum inlet conditions.

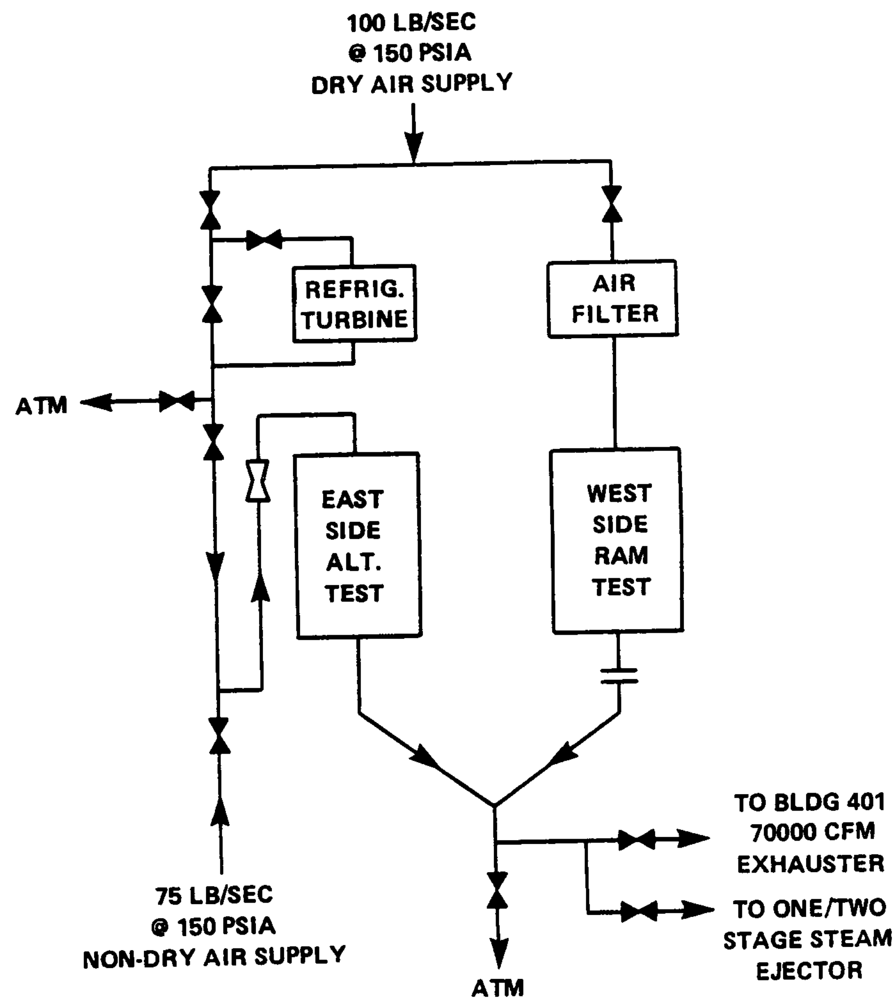
DATA ACQUISITION: 1100 parameters.

CURRENT PROGRAMS: Testing large military turbofan/afterburner engines at altitude flight conditions.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: W. T. Hallmark, M6, GE, Cincinnati, OH 45215, (513) 243-3804/1361.


100
50
20
ATM
10
5
2
1
0.5
PRESSURE (psia)
MAX. DRY AIR SUPPLY
MAX. AIR SUPPLY
MAXIMUM DRY AIR EXHAUST
DRY AIR FLOW (lb/sec)
5
10
20
50
100
175


100 LB/SEC
@ 150 PSIA
DRY AIR SUPPLY
REFRIG.
TURBINE
AIR
FILTER
ATM
EAST
SIDE
ALT.
TEST
WEST
SIDE
RAM
TEST
TO BLDG 401
70000 CFM
EXHAUSTER
TO ONE/TWO
STAGE STEAM
EJECTOR
75 LB/SEC
@ 150 PSIA
NON-DRY AIR SUPPLY
ATM

| General Electric, Cincinnati, OH | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** (ft) 7 x 8 x 16.5 | **MASS FLOW:** (lb/sec) 175 | DOD–AEDC: T-5<br>Allison: 873<br>GE: 117<br>P&W: X-207, X-209<br>NASA–LeRC: PSL-3, PSL-4 |
| | **DATE BUILT/UPGRADED:** 1965 | **ALTITUDE RANGE:** (ft) 85 000 | |
| TC A1 | **REPLACEMENT COST:** $10M | **TEMPERATURE RANGE:** (°F) −70 to +400 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** (psia) 100 | |
| | | **SPEED RANGE:** (Mach No.) 2.5 | |
| | Medium and small turbojet engines | | Group 3 |

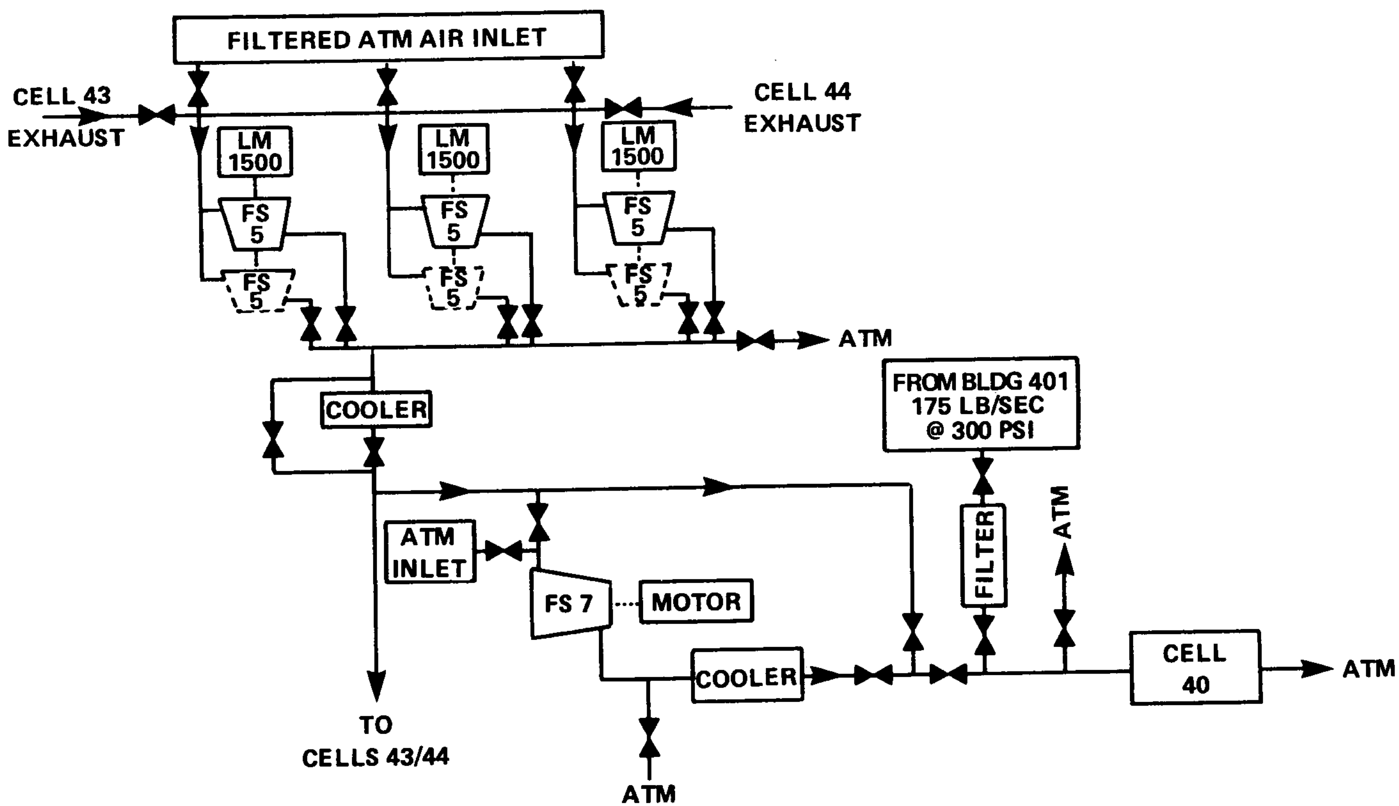
TESTING CAPABILITIES: In addition to the east altitude chamber used for altitude flight testing of small and intermediate size military engines with refrigerated or heated inlet air, there is a west ram-test facility in which core engines are tested at inlet pressure and temperature and extremely high turbine inlet temperatures. Icing and anti-icing tests on small engines are performed in the west setup.

DATA ACQUISITION: 1000+ parameters.

CURRENT PROGRAMS: Testing core engines of military turbojets.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: W. T. Martin, H70, GE, Cincinnati, Ohio 45215, (513) 243-3304/6848.


FILTERED ATM AIR INLET
CELL 43 EXHAUST
CELL 44 EXHAUST
LM 1500
LM 1500
LM 1500
FS 5
FS 5
FS 5
FS 5
FS 5
FS 5
ATM
COOLER
FROM BLDG 401
175 LB/SEC
@ 300 PSI
ATM INLET
FS 7
MOTOR
FILTER
ATM
COOLER
CELL 40
ATM
TO CELLS 43/44
ATM

| General Electric, Cincinnati, OH | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 20 x 20 x 160 | **MASS FLOW:** **(lb/sec)** 450 @ 60 psia<br>1200 @ SLS | NASA–LeRC:<br>PSL-3, PSL-4<br>P&W: X-207, X-208<br>FR–CEPr:<br>R-3, R-4 |
| | **DATE BUILT/UPGRADED:** 1959 | **ALTITUDE RANGE:** **(ft)** 600 (only) | |
| TC 40 | **REPLACEMENT COST:** $7.5M | **TEMPERATURE RANGE:** **(°F)** +100 to +400 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** 60 | |
| | | **SPEED RANGE:** **(Mach No.)** 2.5 | |
| | Medium and small turbojets | | Group 3 |

TESTING CAPABILITIES: Cell 40 is used for cyclic endurance testing of military engines at elevated inlet temperature and pressure. An inlet waste air system permits high-speed throttle bursts, chops, and bogies at constant elevated inlet pressure and temperature. Core engines are tested at very high inlet pressure and temperature.

DATA ACQUISITION: 800 parameters.

CURRENT PROGRAMS: Cyclic endurance testing of military turbojet engines.

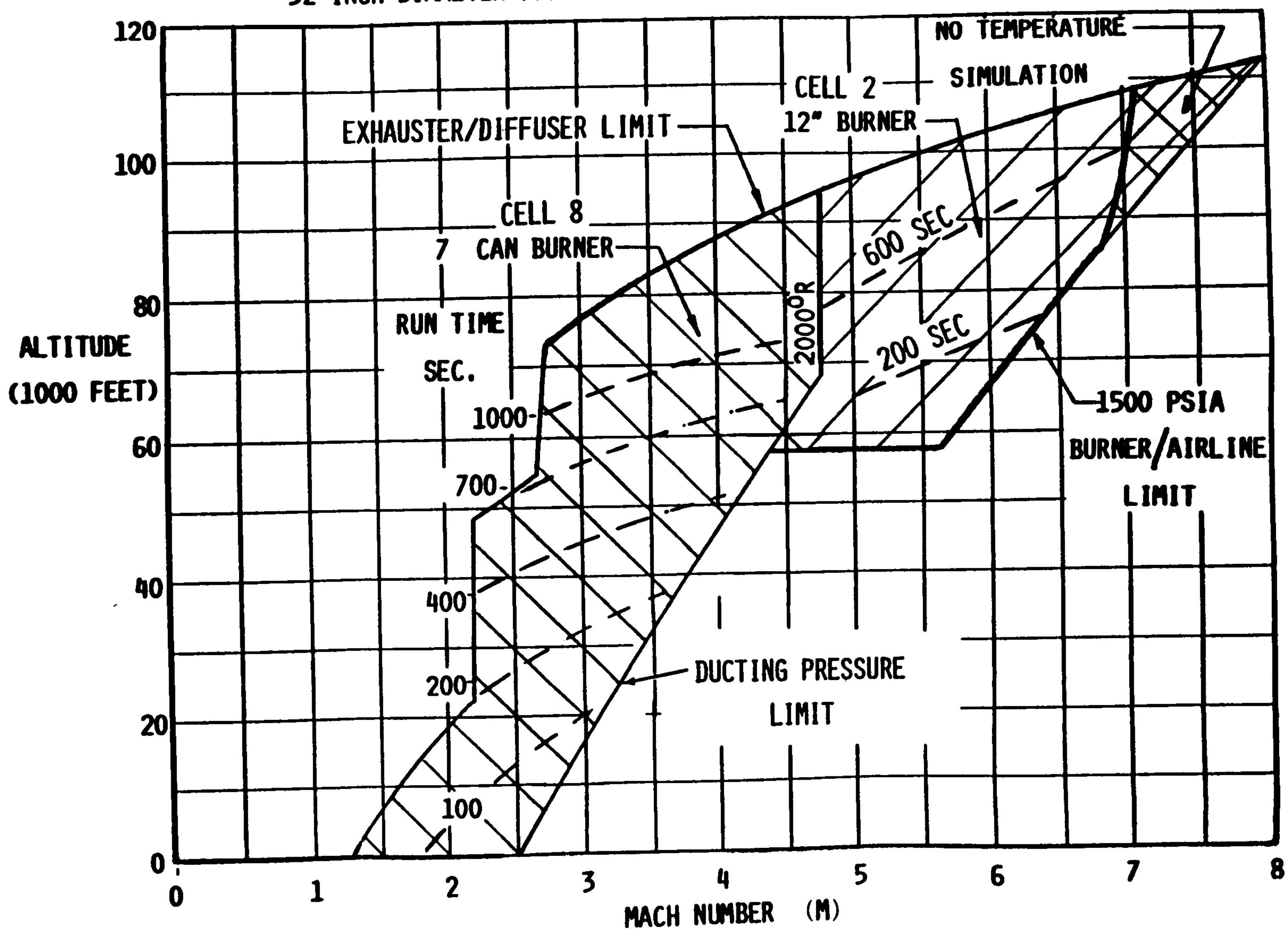
PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: W. T. Hallmark, M6, GE, Cincinnati, Ohio 45215, (513) 243-3804/1361.

MARQUARDT JET LABORATORY

FREEJET TEST CAPABILITY

32 INCH DIAMETER FREEJET NOZZLE AND 44 INCH DIAMETER DIFFUSER



| Marquardt Company, Van Nueys, CA | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 12 dia x 60 L | **MASS FLOW:** **(lb/sec)** 400 | DOD–AEDC: APTU |
| | **DATE BUILT/UPGRADED:** 1952 | **ALTITUDE RANGE:** **(ft)** to 110 000 | |
| TC-2 | **REPLACEMENT COST:** | **TEMPERATURE RANGE:** **(°F)** to +5000 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** to 1500 | |
| | | **SPEED RANGE:** **(Mach No.)** 0.8 – 8.0 | |
| | Capacity of installed thrust stands: 100 000 (lb/f)<br>Ramjets, turbojets, turbofans, and afterburners | | Group 4 |

TESTING CAPABILITIES: Cell 2 is used for performance and development testing of full-scale air-breathing engines. Freejet and direct-connect testing are both accommodated in this cell.

DATA ACQUISITION: A computer-controlled digital data acquisition system is connected to Cell 2. 240 channels are available at a maximum sampling rate of 10 kHz. On-line performance calculations with three CRT displays of temperature bar charts and/or performance plots in addition to 16 digital displays of performance parameters in real time. Engineering unit data listings are available within 0.5 hour after a run, and performance calculations and plots are available within 2 hours after a run.

CURRENT PROGRAMS: Testing ramjets.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Robert Sforzini, Manager-Test, (818) 989-6320.

| | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| Marquardt Company, Van Nueys, CA | **TEST CHAMBER SIZE:** **(ft)** 14 dia x 80 L | **MASS FLOW:** **(lb/sec)** 1200 | DOD–AEDC: APTU |
| | **DATE BUILT/UPGRADED:** 1956 | **ALTITUDE RANGE:** **(ft)** to 100 000 | |
| TC-8 | **REPLACEMENT COST:** Not available | **TEMPERATURE RANGE:** **(°F)** to +5000 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** to 300 | |
| | | **SPEED RANGE:** **(Mach No.)** 0.8 – 8.0 | |
| | Capacity of installed thrust stand: 40 000 (lb/f)<br>Ramjets, turbojets, turbofans, and afterburners | | Group 4 |

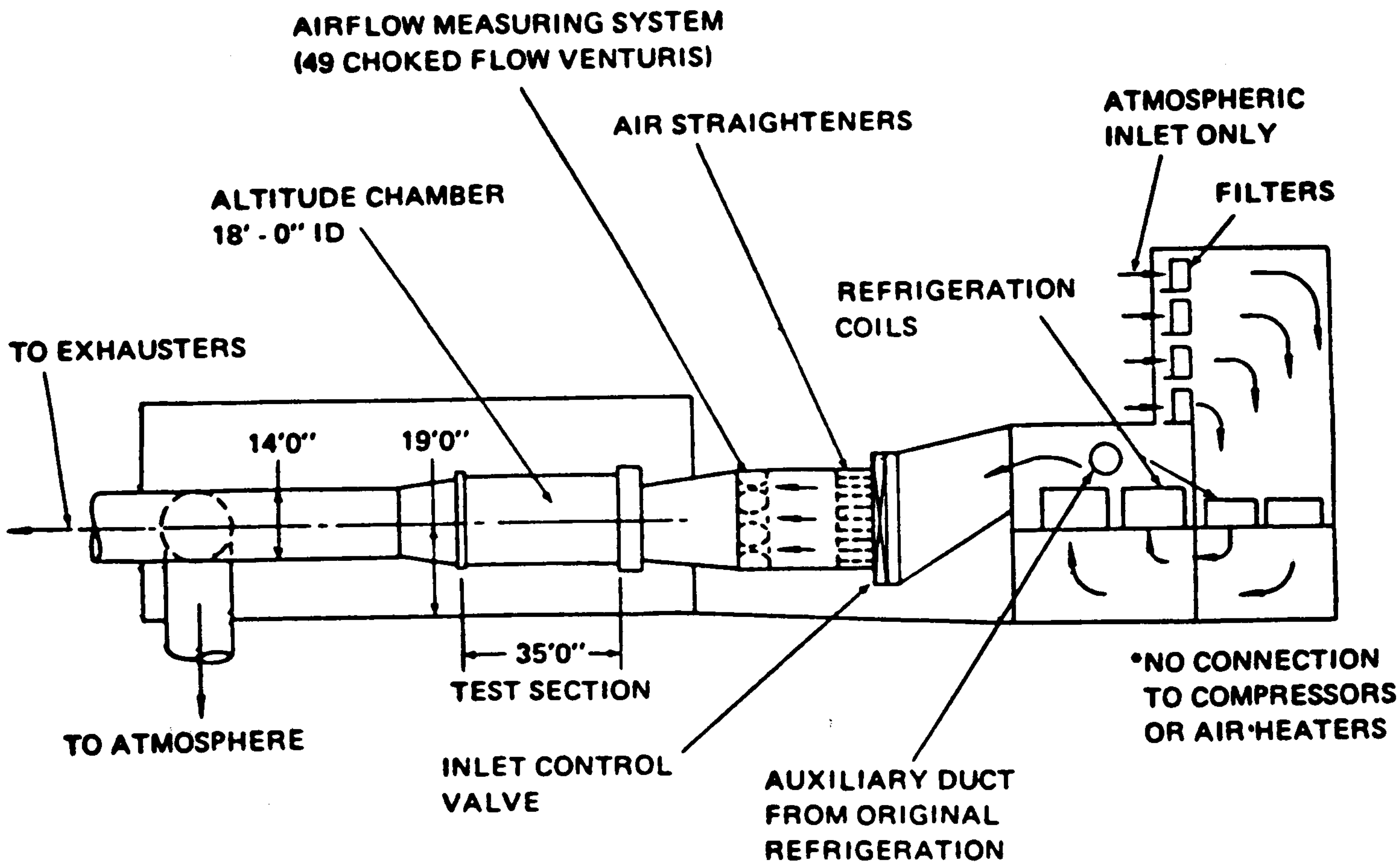
TESTING CAPABILITIES: Cell 8 is used for performance and development testing of full-scale air-breathing engines. Freejet and direct-connect testing are both accommodated in this cell.

DATA ACQUISITION: A computer-controlled digital data acquisition system is connected to Cell 8. 240 channels are available at a maximum sampling rate of 10 kHz. On-line performance calculations with three CRT displays of temperature bar charts and/or performance plots in addition to 16 digital displays of performance parameters in real time. Engineering unit data listings are available within 0.5 hour after a run, and performance calculations and plots are available within 2 hours after a run.

CURRENT PROGRAMS: Testing ramjets.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Robert Sforzini, Manager-Test, (818) 989-6320.


AIRFLOW MEASURING SYSTEM
(49 CHOKED FLOW VENTURIS)
AIR STRAIGHTENERS
ATMOSPHERIC
INLET ONLY
FILTERS
ALTITUDE CHAMBER
18' - 0" ID
REFRIGERATION
COILS
TO EXHAUSTERS
14'0"
19'0"
35'0"
TEST SECTION
TO ATMOSPHERE
INLET CONTROL
VALVE
AUXILIARY DUCT
FROM ORIGINAL
REFRIGERATION
*NO CONNECTION
TO COMPRESSORS
OR AIR-HEATERS

| Pratt & Whitney, East Hartford, CT | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** (ft) 18 dia x 35 L | **MASS FLOW:** (lb/sec) 750; 1200 | DOD–AEDC: T-1, T-2, T-4<br>U.K.–RAE (Pye): C-1, C-2, C-3, C-4 |
| | **DATE BUILT/UPGRADED:** 1968 | **ALTITUDE RANGE:** (ft) SL – 40 000 | |
| X-217 | **REPLACEMENT COST:** $75M | **TEMPERATURE RANGE:** (°F) −10 to +90 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** (psia) 12.5; 12.5 | |
| | | **SPEED RANGE:** (Mach No.) 1.0 | |
| | Thrust measurements to 50 000 lb<br>Critical flow venturi airflow measurement system<br>Large high-bypass turbofans | | Group 1 |

TESTING CAPABILITIES: X-217 stand is a chamber-equipped altitude test stand designed to test the company's largest turbofan or turbojet engines over a flight range of sea level to 40 000 ft altitude and up to Mach 1.0.

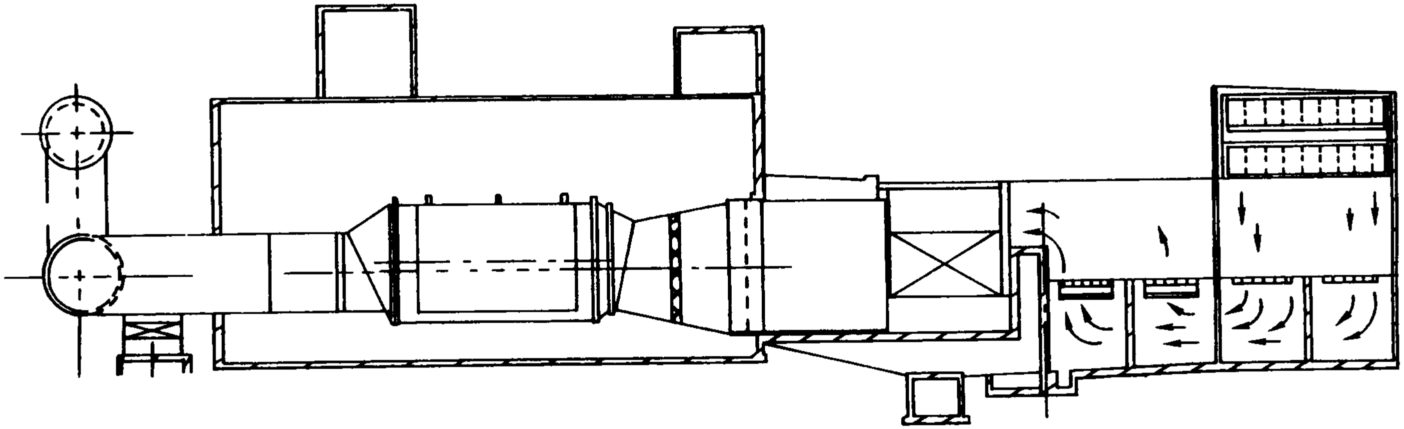
DATA ACQUISITION: A "Steady State II" data acquisition system with 1620 data channels, 702 temperatures, 1160 pressures, 240 transients, and 40 miscellaneous. Data are transmitted to a central computer and returned to the stand printer and alphanumeric scope within 2 minutes. A high-speed option (fast scan) scans up to 240 channels per second and records them on tape. A selected number of fast scans can be transmitted to the central computer and returned in 30 seconds.

CURRENT PROGRAMS: Turbofan engines.

PLANNED IMPROVEMENTS:

LOCAL INFORMATION CONTACT: Joseph A. Barlock, Manager, Experimental Test Equipment Engineering, East Hartford, Connecticut, (203) 565-2091.

83A



| | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| Pratt & Whitney, East Hartford, CT | **TEST CHAMBER SIZE:** **(ft)** 24 dia x 45 L | **MASS FLOW:** **(lb/sec)** 750; 1200 | DOD–AEDC: T-1, T-2, T-4, J-1, J-2<br>U.K.–RAE (Pye): C-1, C-2, C-3, C-3W, C-4 |
| | **DATE BUILT/UPGRADED:** 1980 | **ALTITUDE RANGE:** **(ft)** SL to 40 000 | |
| X-218 | **REPLACEMENT COST:** $20M | **TEMPERATURE RANGE:** **(°F)** −10 to +90 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** 12.5; 12.5 | |
| | | **SPEED RANGE:** **(Mach No.)** 1.0 | |
| | Thrust measurements to 100 000 lb<br>Critical flow venturi airflow measurement system<br>Large high-bypass turbofans | | Group 1 |

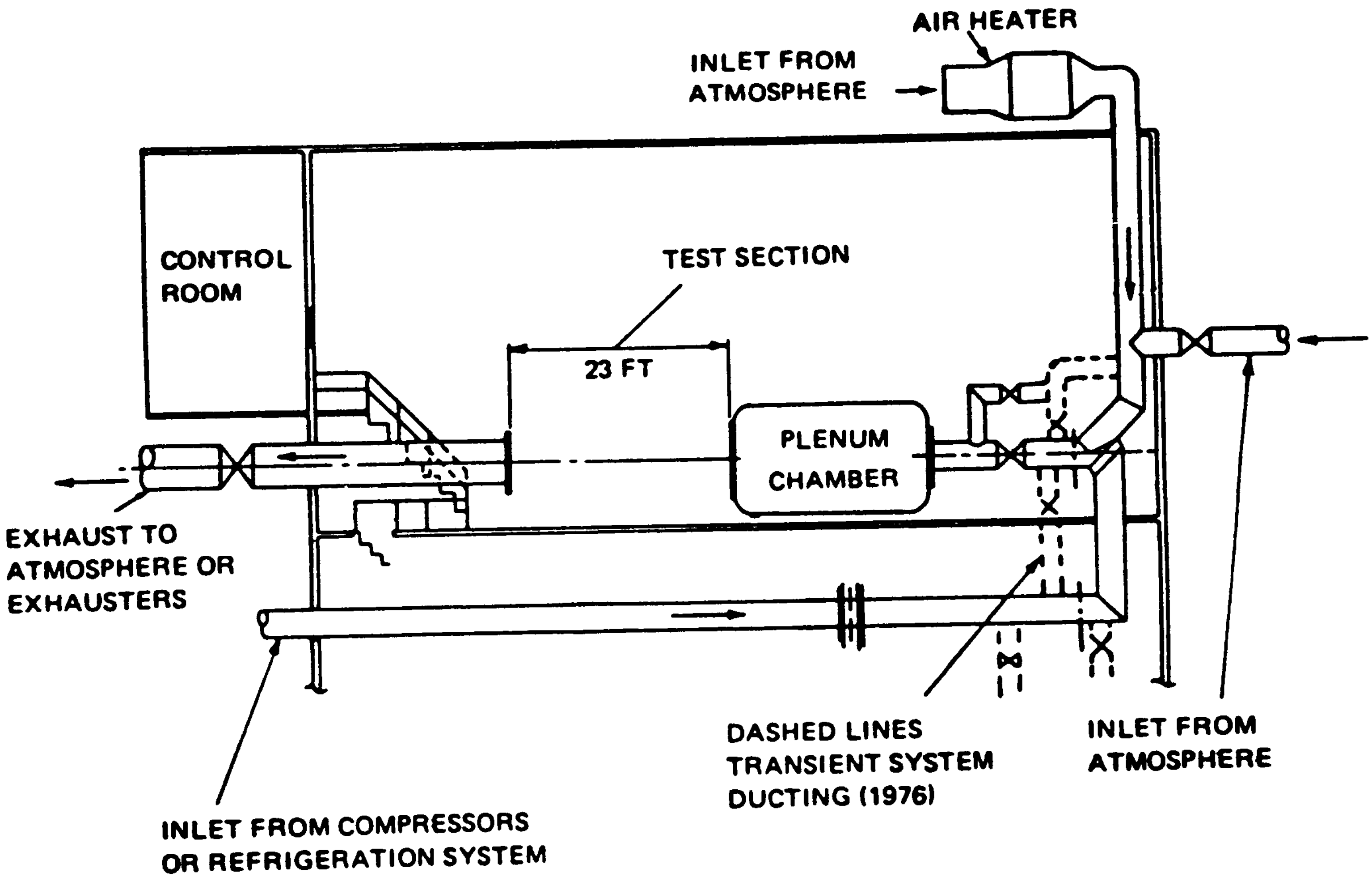
TESTING CAPABILITIES: X-218 stand is a chamber-equipped altitude test stand designed to test the company's largest turbofan engines at subsonic Mach numbers and altitudes up to 40 000 ft.

DATA ACQUISITION: A "Steady State II" data acquisition system (SSDAS II) with 2142 input channels, 1160 pressures, 702 temperatures, 240 transients, and 40 miscellaneous. Data are transmitted to a central computer and returned to a stand printer and alphanumeric scope within 2 minutes. A high-speed option (fast scan) scans up to 240 channels per second and records them on tape. A selected number of fast scans can be transmitted to the computer and returned in 30 seconds.

CURRENT PROGRAMS: Turbofan engines.

PLANNED IMPROVEMENTS:

LOCAL INFORMATION CONTACT: Joseph A. Barlock, Manager, Experimental Test Equipment Engineering, East Hartford, Connecticut, (203) 565-2091.


AIR HEATER
INLET FROM ATMOSPHERE
CONTROL ROOM
TEST SECTION
23 FT
PLENUM CHAMBER
EXHAUST TO ATMOSPHERE OR EXHAUSTERS
INLET FROM COMPRESSORS OR REFRIGERATION SYSTEM
DASHED LINES TRANSIENT SYSTEM DUCTING (1976)
INLET FROM ATMOSPHERE

<table>
<tr><td rowspan="2">Pratt & Whitney,<br>East Hartford, CT</td><td colspan="2">ALTITUDE ENGINE TEST FACILITIES</td><td>COMPARABLE FACILITIES</td></tr>
<tr><td>TEST CHAMBER SIZE:<br>(ft) 23 L</td><td>MASS FLOW:<br>(lb/sec) 200; 325; 580</td><td rowspan="6">NASA–LeRC:<br>PSL-3, PSL-4<br>DOD–AEDC:<br>T-1, T-2, T-4,<br>J-1, J-2<br>U.K.–RAE (Pye):<br>ATF C-2, ATF C-3<br>FR–CEPr: R-3, R-4</td></tr>
<tr><td rowspan="6">X-207</td><td>DATE BUILT/UPGRADED: 1954</td><td>ALTITUDE RANGE: SL – 80 000<br>(ft) @ M = 3.0</td></tr>
<tr><td>REPLACEMENT COST: $8M</td><td>TEMPERATURE RANGE:<br>(°F) –20; +625; +280</td></tr>
<tr><td rowspan="3">OPERATIONAL STATUS:<br><br>Active</td><td>PRESSURE RANGE:<br>(psia) 45; 35; 12.5</td></tr>
<tr><td>SPEED RANGE:<br>(Mach No.) to 3.0</td></tr>
<tr><td></td></tr>
<tr><td colspan="2">Orifice airflow measurement<br>Thermal cyclic inlet system</td><td>Group 2</td></tr>
</table>

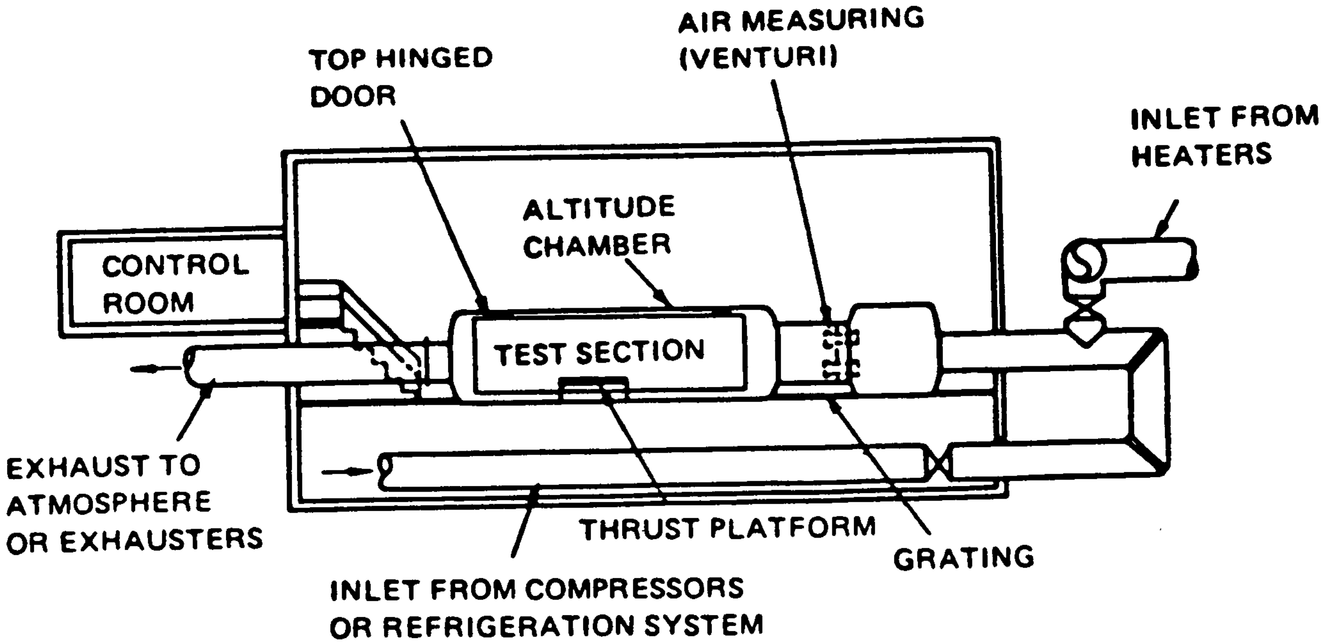
TESTING CAPABILITIES: X-207 stand is a duct-connected altitude test stand. It is designed to test full-sized gas turbine engines with afterburners at various flight conditions up to Mach 3. It can also be used for testing full-scale afterburner component rigs or any miscellaneous component requiring the laboratory air services.

DATA ACQUISITION: An "Astrodata" steady-state data recording system with 686 data channels, 250 temperatures, 420 pressures, and 16 frequencies. Data are transmitted to a central computer and returned to a printer on the stand within 3 minutes.

CURRENT PROGRAMS: Turbojet, turbofan, high-spool (core) engines, afterburner component.

PLANNED IMPROVEMENTS:

LOCAL INFORMATION CONTACT: Joseph A. Barlock, Manager, Experimental Test Equipment Engineering, East Hartford, Connecticut, (203) 565-2091.


AIR MEASURING
(VENTURI)
TOP HINGED
DOOR
INLET FROM
HEATERS
ALTITUDE
CHAMBER
CONTROL
ROOM
TEST SECTION
EXHAUST TO
ATMOSPHERE
OR EXHAUSTERS
THRUST PLATFORM
GRATING
INLET FROM COMPRESSORS
OR REFRIGERATION SYSTEM

| Pratt & Whitney, East Hartford, CT | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 12 dia x 34 L | **MASS FLOW:** **(lb/sec)** 200; 325; 580 | NASA–LeRC: PSL-3, PSL-4<br>DOD–AEDC: T-1, T-2, T-4, J-1, J-2<br>U.K.–RAE (Pye): ATF C-2, ATF C-3<br>FR–CEPr: R-3, R-4 |
| | **DATE BUILT/UPGRADED:** 1954 | **ALTITUDE RANGE:** **(ft)** SL – 80 000 @ M = 3.0 | |
| X-208 | **REPLACEMENT COST:** $8M | **TEMPERATURE RANGE:** **(°F)** −20; +625; +280 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** 45; 35; 12.5 | |
| | | **SPEED RANGE:** **(Mach No.)** to 3.0 | |
| | Thrust measurement to 25 000 lb<br>Critical flow venturi airflow measurement system<br>Large turbojets and low-bypass turbofans | | Group 2 |

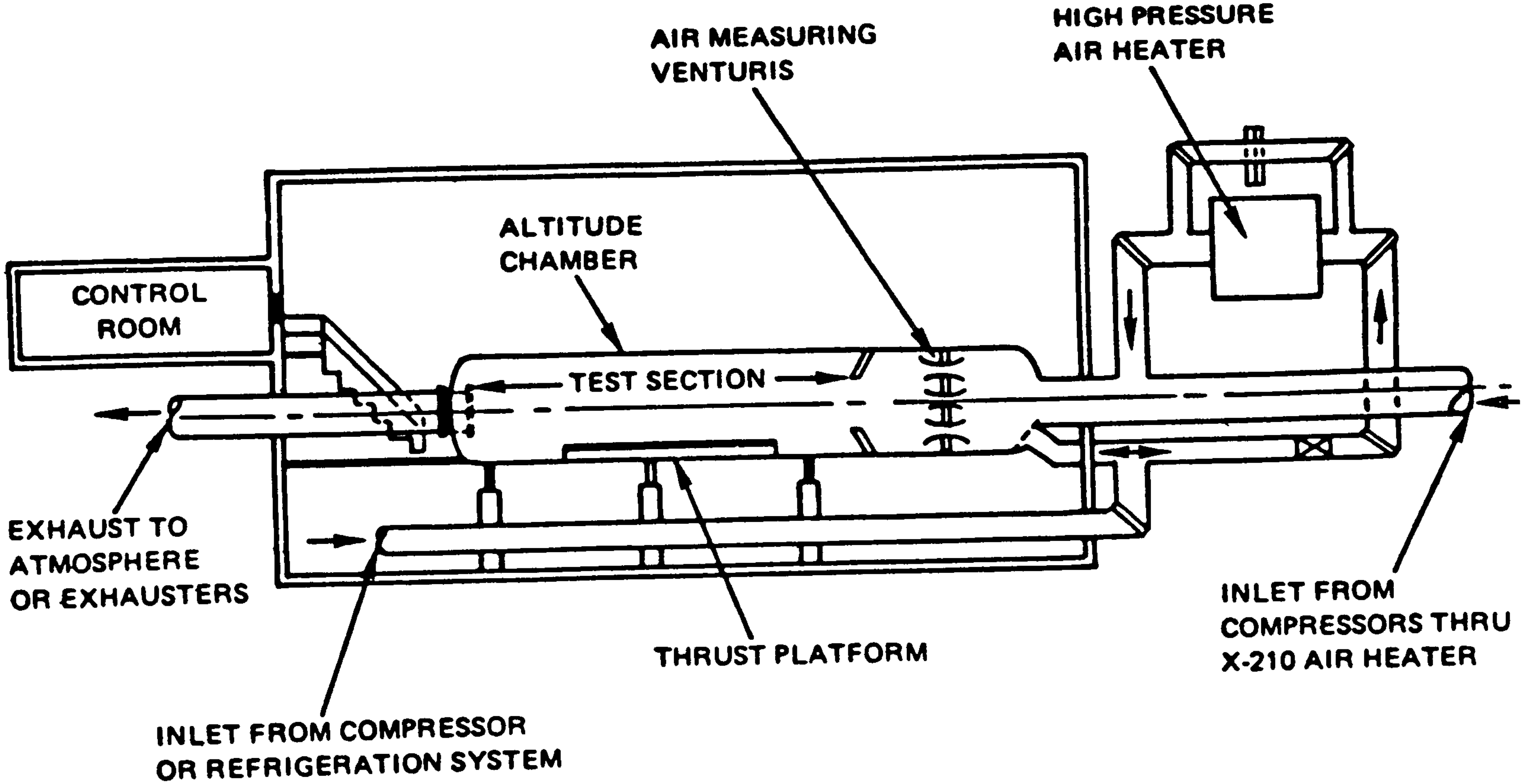
TESTING CAPABILITIES: X-208 stand is a chamber-equipped altitude test stand designed to test full-scale gas turbine engines with or without thrust augmentation devices, afterburner component test rigs, high-spool (core) engines, or any component requiring the laboratory air services.

DATA ACQUISITION: An "Astrodata" steady-state data recording system with 686 data channels, 250 temperatures, 420 pressures, and 16 frequencies. Data are transmitted to a central computer and returned to a line printer at the stand within 3 minutes. Up to 400 transient signals can be recorded by a mobile van connected to the stand.

CURRENT PROGRAMS: Turbofan, turbojet, high-spool engines, afterburner component.

PLANNED IMPROVEMENTS:

LOCAL INFORMATION CONTACT: Joseph A. Barlock, Manager, Experimental Test Equipment Engineering, East Hartford, Connecticut, (203) 565-2091.


AIR MEASURING
VENTURIS
HIGH PRESSURE
AIR HEATER
ALTITUDE
CHAMBER
CONTROL
ROOM
TEST SECTION
EXHAUST TO
ATMOSPHERE
OR EXHAUSTERS
THRUST PLATFORM
INLET FROM
COMPRESSORS THRU
X-210 AIR HEATER
INLET FROM COMPRESSOR
OR REFRIGERATION SYSTEM

| Pratt & Whitney, East Hartford, CT | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 12 dia x 34 L | **MASS FLOW:** **(lb/sec)** 200; 325; 125 | NASA–LeRC: PSL-3, PSL-4<br>DOD–AEDC: T-1, T-2, T-4, J-1, J-2<br>U.K.–RAE (Pye): ATF C-2, ATF C-3<br>FR–CEPr: R-3, R-4 |
| | **DATE BUILT/UPGRADED:** 1954 | **ALTITUDE RANGE:** **(ft)** SL – 80 000 @ M = 3.0 | |
| X-209 | **REPLACEMENT COST:** $10M | **TEMPERATURE RANGE:** **(°F)** −20; +625; +650 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** 125; 35; 12.5 | |
| | | **SPEED RANGE:** **(Mach No.)** to 3.0 | |
| | Thrust measurement to 25 000 lb<br>Critical flow venturi airflow measurement system<br>Medium and small turbojets | | Group 3 |

TESTING CAPABILITIES: X-209 stand is a chamber-equipped altitude test stand designed to test full-scale gas turbine engines with or without thrust augmentation devices, afterburner component test rigs, high-spool (core) engines, or any component requiring the laboratory air services.

DATA ACQUISITION: An "Astrodata" steady-state data recording system with 686 data channels, 250 temperatures, 420 pressures, and 16 frequencies. A "Sigma 8" system with 327 data channels, 116 temperatures, 204 pressures, and 7 frequencies. Both systems are connected to the central computer. Data are returned to the stand printer or alphanumeric scope within 3 minutes. Up to 400 transient signals can be recorded by a mobile van connected to the stand.

CURRENT PROGRAMS: Turbofan, turbojet, high-spool (core) engines, afterburner components.

PLANNED IMPROVEMENTS:

LOCAL INFORMATION CONTACT: Joseph A. Barlock, Manager, Experimental Test Equipment Engineering, East Hartford, Connecticut, (203) 565-2091.

| National Research Council of Canada | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 7 dia x 12 L | **MASS FLOW:** **(lb/sec)** 0 – 12 | Allison: 885 |
| | **DATE BUILT/UPGRADED:** 1967/1979 | **ALTITUDE RANGE:** **(ft)** SL – 45 000 | |
| Altitude Test Chamber | **REPLACEMENT COST:** $1M | **TEMPERATURE RANGE:** **(°F)** –70 to +212 | |
| | **OPERATIONAL STATUS:** Active | **PRESSURE RANGE:** **(psia)** 1 – 160 | |
| | | **SPEED RANGE:** **(Mach No.)** 0 – 0.7 | |
| | Altitude performance of small (up to circa 2000 hp) turboprops, turbofan gas generators<br>Cold start testing<br>Nacelle deicing | | Group 3 |

TESTING CAPABILITIES: The facility is used primarily for the altitude performance testing of small aviation gas turbine engines. The main air supply component is a 2000 kW centrifugal exhauster operating at an inlet volume of 800 $ft^3$/sec over an available inlet pressure range of 1–3 psia. Additional air supplies (up to 11 lb/sec at 300 psi) are used for in-chamber testing at atmospheric pressure and above (e.g., cold starts) and for injector drive in an associated nacelle deicing rig. The refrigeration package is rated at 90 tons (–70°F at 4 lb/sec).

CURRENT PROGRAMS: Turboprop altitude performance, cold start, nacelle deicing.

PLANNED IMPROVEMENTS: An additional 7.5 MW compressor/exhauster for general purposes is currently being installed (operational, late 1984). Applied to the Altitude Test Chamber, this will potentially double the present facility limits (for altitude testing) with respect to engine size.

LOCAL INFORMATION CONTACT: R. A. Tyler, Head, Gas Dynamics Laboratory, National Research Council of Canada, Ottawa, Ontario K1A OR6, (613) 993-2442.

| CEPr, Saclay, France<br>R-3 | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 11.5 dia x 60 L | MASS FLOW: (lb/sec) 441 | DOD–AEDC: C-1, C-2, T-1, T-2, T-4<br>DOD–NAPC: 1E, 2E, 3E<br>NASA–LeRC: PSL-3, PSL-4<br>GR–University of Stuttgart: 14 AT<br>U.K.–Rolls Royce: ATF C-1, ATF C-2 |
| | DATE BUILT/UPGRADED: | ALTITUDE RANGE: (ft) 65 600 | |
| | REPLACEMENT COST: | TEMPERATURE RANGE: (°F) −85 to +390 | |
| | OPERATIONAL STATUS: | PRESSURE RANGE: (psia) 30 | |
| | | SPEED RANGE: (Mach No.) 0 – 2.4 | |
| | Freejet and direct-connect<br>Small turbojets | | Groups 3, 4 |

| CEPr, Saclay, France<br>R-4 | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 11.5 dia x 60 L | MASS FLOW: (lb/sec) 441 | NASA–LeRC: PSL-3, PSL-4<br>DOD–AEDC: C-1, C-2, T-1, T-2, T-4<br>DOD–NAPC: 1E, 2E, 3E |
| | DATE BUILT/UPGRADED: | ALTITUDE RANGE: (ft) 65 600 | |
| | REPLACEMENT COST: | TEMPERATURE RANGE: (°F) −85 to +370 | |
| | OPERATIONAL STATUS: | PRESSURE RANGE: (psia) 30 | |
| | | SPEED RANGE: (Mach No.) 0 – 2.4 | |
| | Freejet and direct-connect medium and small turbojets | | Groups 3, 4 |

| CEPr, Saclay, France | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** (ft) 18 dia x 100 L | **MASS FLOW:** (lb/sec) 825 | NASA–LeRC: PSL-4<br>DOD–AEDC: C-1<br>U.K.–RAE (Pye): ATF C-4 |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE:** (ft) 65 600 | |
| R-5 | **REPLACEMENT COST:** | **TEMPERATURE RANGE:** (°F) +1200 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE:** (psia) 100 | |
| | | **SPEED RANGE:** (Mach No.) 0 – 4.0 | |
| | Capacity of installed thrust stand: ±67 500 (lb/f)<br>Direct-connect and freejet | | Groups 2, 4 |

| CEPr, Saclay, France | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** (ft) 11 dia x 26 L | **MASS FLOW:** (lb/sec) 121 | GR–University of Stuttgart: HPT |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE:** (ft) 36 000 | |
| C-1 | **REPLACEMENT COST:** | **TEMPERATURE RANGE:** (°F) −86 to +175 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE:** (psia) 7 – 17 | |
| | | **SPEED RANGE:** (Mach No.) 0 – 1 | |
| | Capacity of installed thrust stand: ±2250 (lb/f)<br>Freejet and direct-connect turboshaft engines 27 000 hp | | Groups 3, 4 |

| CEPr, Saclay, France | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) | MASS FLOW: (lb/sec) 221 | |
| | DATE BUILT/UPGRADED: | ALTITUDE RANGE: (ft) 62 000 | |
| S-1 | REPLACEMENT COST: | TEMPERATURE RANGE: (°F) +661 | |
| | OPERATIONAL STATUS: | PRESSURE RANGE: (psia) 29 | |
| | | SPEED RANGE: (Mach No.) | |
| | | | Groups 3, 4 |

| University of Stuttgart, West Germany<br><br>HPT | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** (ft) 10 dia x 33 L | **MASS FLOW:** (lb/sec) 154 | NASA–LeRC: PSL-3, PSL-4<br>DOD–NAPC: 1E, 2E, 3E<br>U.K.–Rolls Royce: ATF C-1, ATF C-2<br>U.K.–RAE (Pye): ATF C-3<br>FR–CEPr: R-3, R-4 |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE:** (ft) 65 600 | |
| | **REPLACEMENT COST:** | **TEMPERATURE RANGE:** (°F) −100 to +350 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE:** (psia) 28 | |
| | | **SPEED RANGE:** (Mach No.) 0 – 2.2 | |
| | Capacity of installed thrust stand capability: 22 500 (lb/f)<br>Direct-connect and freejet<br>Turboshaft capability: 6000 hp, full engine and flight environment transient | | Groups 3, 4 |

| Mitsubishi Heavy Industries, Ltd., Japan | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** Direct Connect **(ft)** 8 dia x 40 L | **MASS FLOW: (lb/sec)** 12 | Allison: 885<br>Canada–NRC: Alt. Test Chamber |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE: (ft)** SL – 20 000 | |
| Small Turbojet Development Test Cell (1007) | **REPLACEMENT COST:** | **TEMPERATURE RANGE: (°F)** –50 to +180 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE: (psia)** 33 | |
| | | **SPEED RANGE: (Mach No.)** 0 – 1.2 | |
| | Capacity of installed thrust stand: ±1100 (lb/f)<br>Medium and small turbojets | | Group 3 |

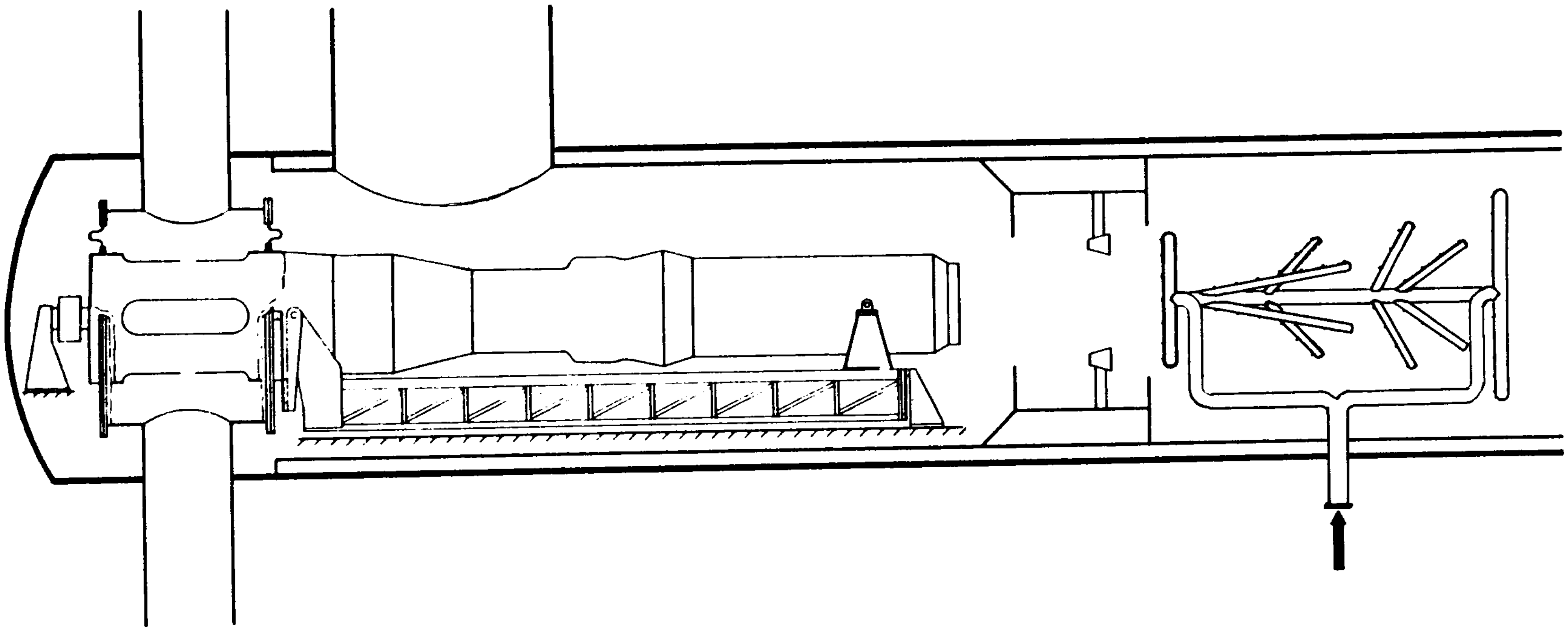
TESTING CAPABILITIES: The 1007 is used mainly for performance and mission simulated testing of small turbojets for missiles and target drones. It also has the environmental test capabilities for high and low temperature and water ingestion.

DATA ACQUISITION: Minicomputer-controlled digital data acquisition system (MEC MELCOM 70/25) is available for high-speed general-purpose data acquisition (64 channels, 6000 samples per second). Personal computer-controlled system is also available for lower speed data acquisition (170 channels). Analog recording devices such as magnetic tape, strip chart, and oscillograph are prepared.

CURRENT PROGRAMS: Testing turbojets.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: T. Aoki, Senior Engineer, Engine Department, Nagoya Aircraft Works, (0569) 79-2111, ext. 232.



| Royal Aircraft Establishment Pyestock, United Kingdom | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 12 dia x 122 L | MASS FLOW: (lb/sec) 450 max | NASA–LeRc: PSL-3, PSL-4<br>DOD–AEDC: T-1, T-2, T-4<br>FR–CEPr: R-3, R-4, S1<br>U.K.–Rolls Royce: ATF C-2, ATF C-1 |
| | DATE BUILT/UPGRADED: 1954 | ALTITUDE RANGE: (ft) 50 000 | |
| ATF Cell 2 | REPLACEMENT COST: £30M* | TEMPERATURE RANGE: (°F) Ambient to +450 | |
| | OPERATIONAL STATUS: Double day shift | PRESSURE RANGE: (psia) 2 – 100 | |
| | | SPEED RANGE: (Mach No.) 0 – 2.5 | |
| | Primarily a connected test cell for turbojet and low bypass ratio engines with air flows up to 450 lb/sec | | Group 3 |

TESTING CAPABILITIES: Cell 2 is used for connected testing of reheat systems, which are supplied with high pressure, high temperature air through a preheater. The cell also may be adapted to test jet engines at conditions representing low altitude and high subsonic speed. Exhaust gases are extracted by four air-driven ejectors.

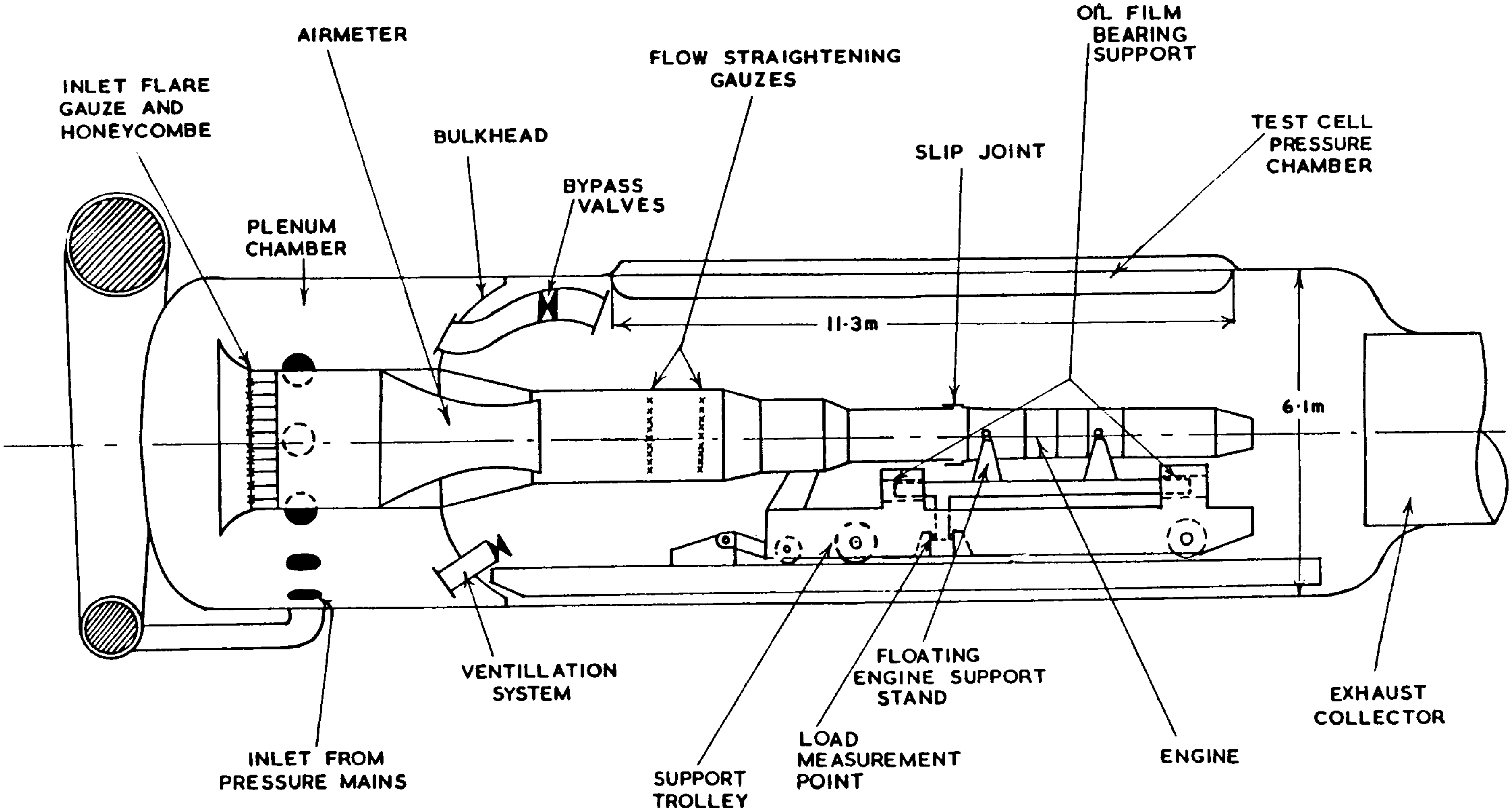
DATA ACQUISITION: Data acquisition and processing are controlled by a Gould computer system, which provides for on-line assessment of plant and test rig behavior. The instrumentation system includes 200 temperatures and 100 individual pressures.

CURRENT PROGRAMS: Support of U.K. military engine development program.

PLANNED IMPROVEMENTS: Uprating of the preheater delivery temperature by the provision of a hydrogen fueled secondary preheater.

LOCAL INFORMATION CONTACT: Head of Propulsion Department, RAE Pyestock, Farnborough, GU14 OLS, Hants, United Kingdom.

*Replacement cost includes a percentage for common services (e.g., air supplies, fuel systems, and central computer).


INLET FLARE GAUZE AND HONEYCOMBE
AIRMETER
PLENUM CHAMBER
BULKHEAD
BYPASS VALVES
FLOW STRAIGHTENING GAUZES
SLIP JOINT
OIL FILM BEARING SUPPORT
TEST CELL PRESSURE CHAMBER
11·3m
6·1m
VENTILLATION SYSTEM
INLET FROM PRESSURE MAINS
SUPPORT TROLLEY
LOAD MEASUREMENT POINT
FLOATING ENGINE SUPPORT STAND
ENGINE
EXHAUST COLLECTOR

| | | | |
|---|---|---|---|
| Royal Aircraft Establishment Pyestock, United Kingdom | **ALTITUDE ENGINE TEST FACILITIES** | | **COMPARABLE FACILITIES** |
| | **TEST CHAMBER SIZE: (ft)** 20 dia x 80 L | **MASS FLOW: (lb/sec)** 600 max | NASA–LeRC: PSL-3, PSL-4<br>DOD–AEDC: T-1, T-2, T-4, C-1, C-2<br>DOD–NAPC: 1E, 2E, 3E |
| | **DATE BUILT/UPGRADED:** 1960 | **ALTITUDE RANGE: (ft)** 65 000 | |
| ATF Cell 3 | **REPLACEMENT COST:** £90M* | **TEMPERATURE RANGE: (°F)** -100 to +880 | |
| | **OPERATIONAL STATUS:** Double day shift | **PRESSURE RANGE: (psia)** 2 – 39 | |
| | | **SPEED RANGE: (Mach No.)** 0 – 2.5 | |
| | Direct-connected and freejet, special capability icing tests<br>High-accuracy thrust requirement measurement capability: 50 000 lb/f | | Groups 2, 4 |

TESTING CAPABILITIES: Primarily used for connected tests on advanced military turbofans and turbojets. Performance evaluation, engine handling, altitude relight, and icing trials are possible over a wide operational envelope. Freejet testing, including icing of smaller engines and components, is an added capability. Cell altitude conditions and exhaust gas extraction are achieved by use of exhauster compressors.

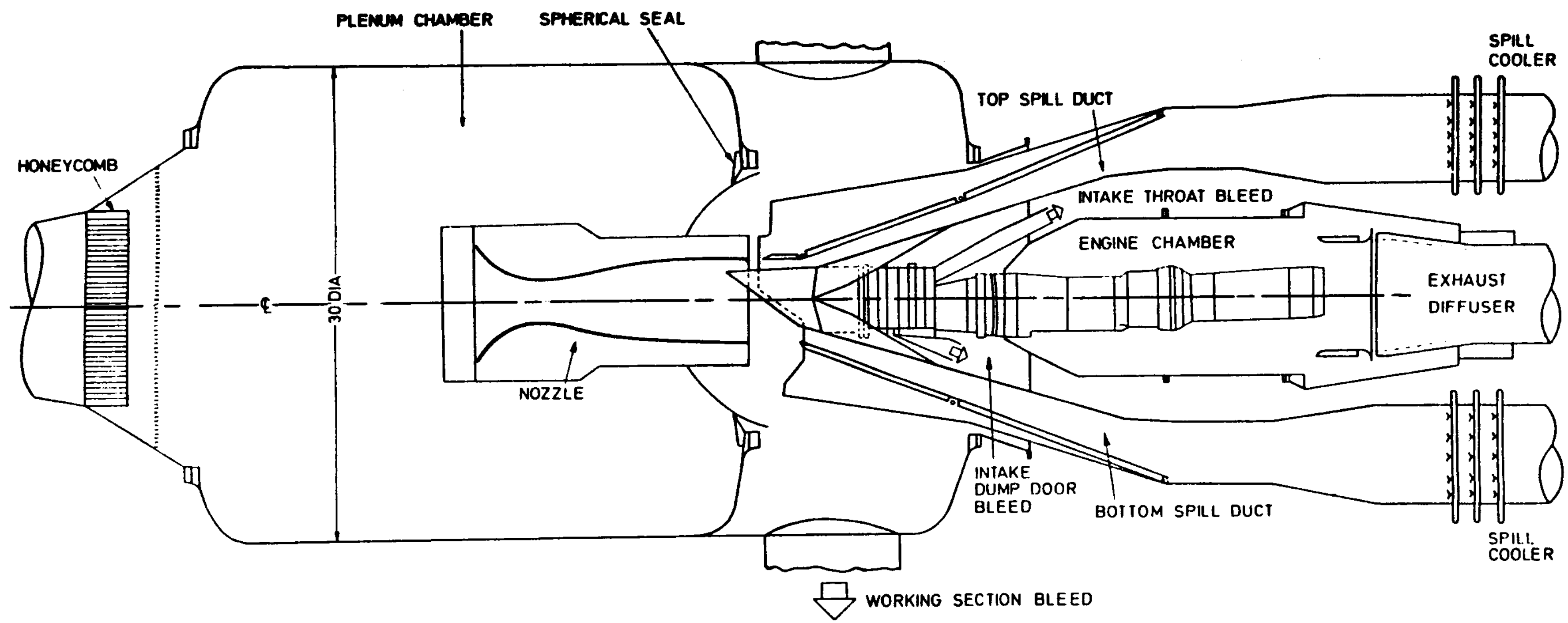
DATA ACQUISITION: Data acquisition and processing is controlled by a Gould computer system, which provides for on-line measurement of plant and test rig behavior. The instrumentation system includes 500 individual pressures and 200 temperatures, fuel flows, shaft speeds, and thrust.

CURRENT PROGRAMS: Support of U.K. military engine development program.

PLANNED IMPROVEMENTS: Replacement of exhaust gas cooler during 1986.

LOCAL INFORMATION CONTACT: Head of Propulsion Department, RAE Pyestock, Farnborough, GU14 OLS, Hants, United Kingdom.

*Replacement cost includes a percentage for common services (e.g., air supplies, fuel systems, and central computer).


PLENUM CHAMBER
SPHERICAL SEAL
SPILL COOLER
TOP SPILL DUCT
HONEYCOMB
INTAKE THROAT BLEED
ENGINE CHAMBER
EXHAUST DIFFUSER
30"DIA
NOZZLE
INTAKE DUMP DOOR BLEED
BOTTOM SPILL DUCT
SPILL COOLER
WORKING SECTION BLEED

| | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| Royal Aircraft Establishment Pyestock, United Kingdom | TEST CHAMBER SIZE: (ft) 30 dia x 69 L | MASS FLOW: (lb/sec) 500 | DOD–AEDC: C-2<br>FR–CEPr: R-5 |
| | DATE BUILT/UPGRADED: 1966 | ALTITUDE RANGE: (ft) 100 000 | |
| ATF Cell 4 | REPLACEMENT COST: £90M | TEMPERATURE RANGE: (°F) Ambient to +880 | |
| | OPERATIONAL STATUS: Standby | PRESSURE RANGE: (psia) 3 – 40 | |
| | | SPEED RANGE: (Mach No.) 1.50 – 3.50 | |
| | Freejet test section, full engine envelope plus flight<br>No thrust measurement capability | | Group 4 |

TESTING CAPBILITIES: Cell 4 is a large freejet supersonic test cell with a variable Mach number blowing nozzle providing variation of incidence and/or yaw while running. It was originally designed to test engines of about 150 lb/s sea level static flow over a range of Mach numbers from 1.5 to 3.5. The size of the blowing nozzle has since been doubled to 25 square feet to enable tests of a Concorde intake and Olympus 593 engine to be carried out over a Mach number range from approximately 1.7 to 2.3. It also has been used for freejet testing of military aircraft intakes plus engine at subsonic speeds.

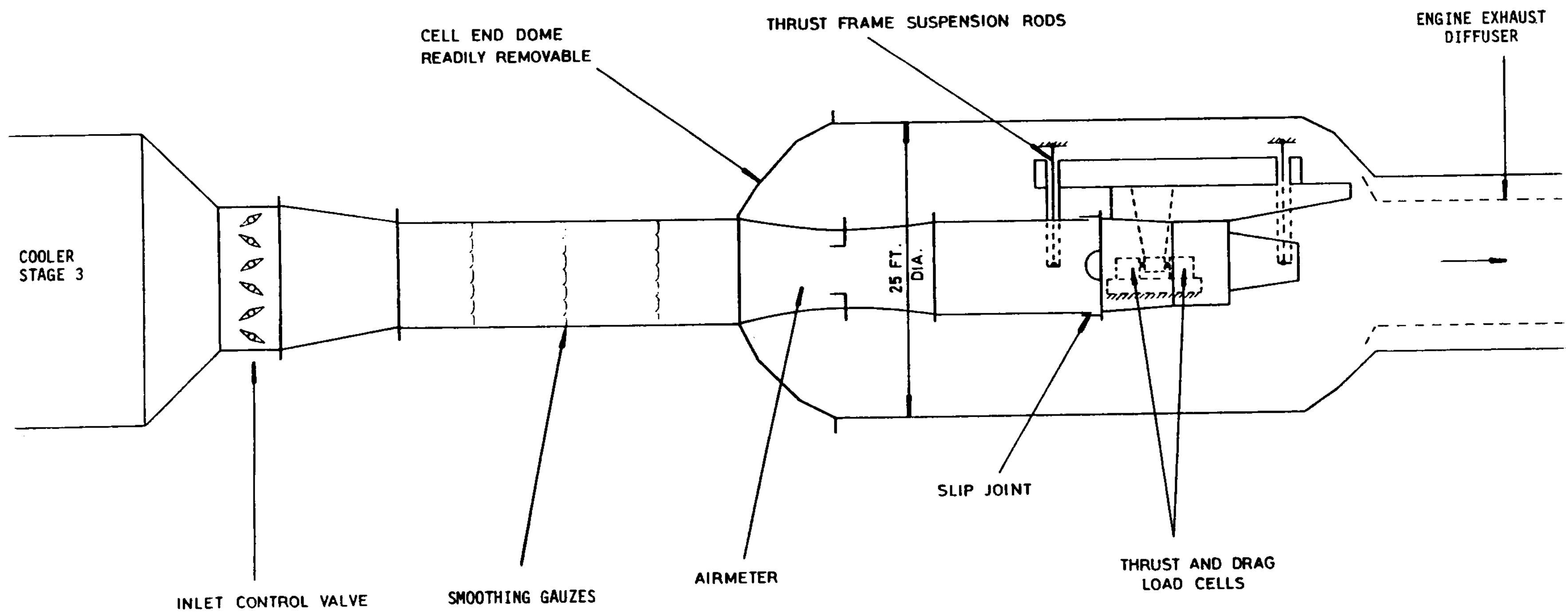
DATA ACQUISITION: A comprehensive data acquisition and processing system controlled by a Gould computer can be provided.

CURRENT PROGRAMS: No current program.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Head of Propulsion Department, RAE Pyestock, Farnborough, GU14 OLS, Hants, United Kingdom.

*Replacement cost includes a percentage for common services (e.g., air supplies, fuel systems, and central computer).


COOLER
STAGE 3
INLET CONTROL VALVE
SMOOTHING GAUZES
CELL END DOME
READILY REMOVABLE
AIRMETER
25 FT.
DIA.
THRUST FRAME SUSPENSION RODS
SLIP JOINT
THRUST AND DRAG
LOAD CELLS
ENGINE EXHAUST
DIFFUSER

| Royal Aircraft Establishment Pyestock, United Kingdom | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | TEST CHAMBER SIZE: (ft) 25 dia x 56 L | MASS FLOW: (lb/sec) 1400 | DOD–AEDC: J-1, J-2, C-1, C-2<br>P&W: X-217, X-218 |
| | DATE BUILT/UPGRADED: 1969 | ALTITUDE RANGE: (ft) 50 000 | |
| ATF Cell 3W | REPLACEMENT COST: £60M* | TEMPERATURE RANGE: (°F) -50 to ambient | |
| | OPERATIONAL STATUS: Double day shift | PRESSURE RANGE: (psia) 2 to atmospheric | |
| | | SPEED RANGE: (Mach No.) Subsonic | |
| | Direct-connected and freejet, high-accuracy thrust capability: 6000 lb/f<br>Special capability is connected or free icing. | | Group 4 |

TESTING CAPABILITIES: Primarily used for connected testing of high bypass ratio turbofans up to 60 000 lb/f thrust, but also can be employed on icing trials on full-scale helicopter fuselages. Intake air is drawn from atmosphere through inlet cooler, which is refrigerated using aqueous ammonia. Cell altitude conditions and exhaust gas extraction are achieved by use of exhauster compressors.

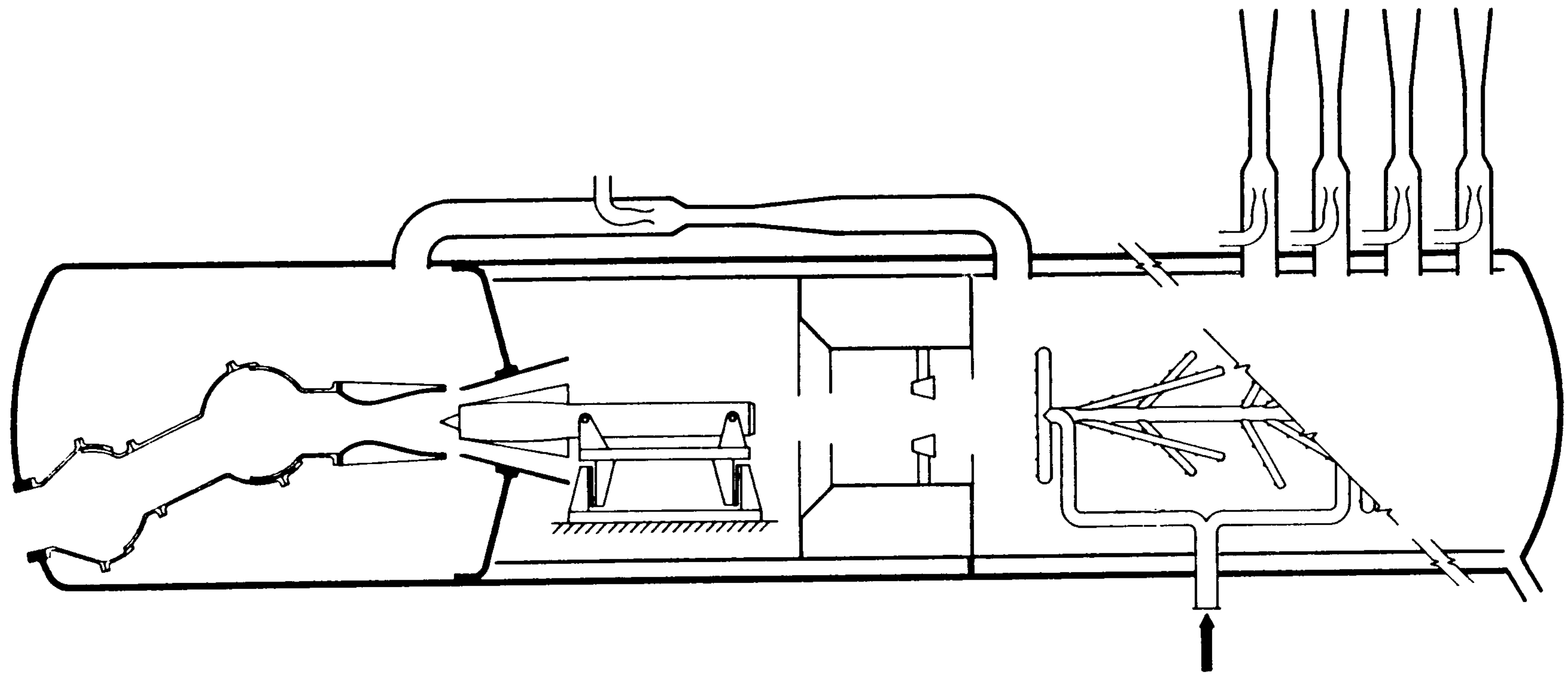
DATA ACQUISITION: Data acquisition and processing is controlled by a Gould computer system, which provides for on-line measurement of plant and test rig behavior. The instrumentation system includes 200 individual pressures, 500 pressures on scanivalve, 800 temperatures, fuel flows, shaft speed, and thrust.

CURRENT PROGRAMS: Support of U.K. civil engine development program and helicopter icing.

PLANNED IMPROVEMENTS: No major changes are planned.

LOCAL INFORMATION CONTACT: Head of Propulsion Department, RAE Pyestock, Farnborough, GU14 OLS, Hants, United Kingdom.

*Replacement cost includes a percentage for common services (e.g., air supplies, fuel systems, and central computer).



| Royal Aircraft Establishment Pyestock, United Kingdom | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** (ft) 12 dia x 122 L | **MASS FLOW:** (lb/sec) 450 max | DOD–AEDC: T-1, T-2, T-4<br>FR–CEPr: R-5 |
| | **DATE BUILT/UPGRADED:** 1954/1984 | **ALTITUDE RANGE:** (ft) 50 000 | |
| ATF Cell 1 | **REPLACEMENT COST:** £30M* | **TEMPERATURE RANGE:** (°F) Ambient to 450 | |
| | **OPERATIONAL STATUS:** Double day shift | **PRESSURE RANGE:** (psia) 2 – 100 | |
| | | **SPEED RANGE:** (Mach No.) 0 – 3.5 | |
| | Primarily freejet supersonic, but is being adapted for connected testing of turbojet engines with airflow capability up to 250 lb/sec | | Group 4 |

TESTING CAPABILITIES: This cell was originally designed for the freejet testing of ramjet engines, but has been modified to provide for freejet testing of model air intakes for supersonic aircraft, tests on small turbojet engines, and reheat combustion systems. The upgrading to test military turbofans of low bypass ratio is nearing completion. Cell altitude conditions are achieved using air-driven ejectors.

DATA ACQUISITION: Data acquisition and processing is controlled by a Gould computer system, which is being upgraded to provide for on-line assessment of plant and test rig or engine behavior. The instrumentation system includes 350 pressures by scanivalve, 100 individual pressures, and 200 temperatures.

CURRENT PROGRAMS: Support of U.K. military engine development program.

PLANNED IMPROVEMENTS: Enhancement of data acquisition system.

LOCAL INFORMATION CONTACT: Head of Propulsion Department, RAE Pyestock, Farnborough, GU14 OLS, Hants, United Kingdom.

*Replacement cost includes a percentage for common services (e.g., air supplies, fuel systems, and central computer).

| Rolls Royce, Derby, United Kingdom<br>ATF C-1 | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE: (ft)** 9 dia x 38 L | **MASS FLOW: (lb/sec)** 400 | DOD–AEDC:<br>T-1, T-2, T-4<br>P&W: X-209<br>FR–CEPr:<br>R-3, R-4 |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE: (ft)** 70 000 | |
| | **REPLACEMENT COST:** | **TEMPERATURE RANGE: (°F)** −113 to +355 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE: (psia)** 73 | |
| | | **SPEED RANGE: (Mach No.)** 0 – 2.5 | |
| | Capacity of installed thrust stand: 20 000 (lb/f)<br>Freejet and direct-connect<br>Turboshaft engine to 6 000 hp | | Groups 3, 4 |

| Rolls Royce, Derby, United Kingdom<br>TP 131A | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE: (ft)** 10 dia x 80 L | **MASS FLOW: (lb/sec)** 400 | Marquardt:<br>TC-2, TC-8<br>FR–CEPr:<br>R-5 |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE: (ft)** 90 000 | |
| | **REPLACEMENT COST:** | **TEMPERATURE RANGE: (°F)** 841 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE: (psia)** 165 | |
| | | **SPEED RANGE: (Mach No.)** 0 to 4.2 | |
| | High pressure storage: 72 000 lb air @ 3600 psia<br>Freejet and direct-connect | | Group 4 |

| Rolls Royce, Derby, United Kingdom<br><br>ATF C-2 | ALTITUDE ENGINE TEST FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **TEST CHAMBER SIZE:** **(ft)** 9 dia x 38 L | **MASS FLOW:** **(lb/sec)** 400 | DOD–AEDC: T-1, T-2, T-4<br>P&W: X-208<br>FR–CEPr: R-3, R-4 |
| | **DATE BUILT/UPGRADED:** | **ALTITUDE RANGE:** **(ft)** 70 000 | |
| | **REPLACEMENT COST:** | **TEMPERATURE RANGE:** **(°F)** −113 to +355 | |
| | **OPERATIONAL STATUS:** | **PRESSURE RANGE:** **(psia)** 73 | |
| | | **SPEED RANGE:** **(Mach No.)** 0 – 2.5 | |
| | Capacity of installed thrust stand: ±20 000 (lb/f)<br>Freejet and direct-connect | | Groups 3, 4 |

# ENGINE/PROPULSION COMPONENT FACILITIES

The Engine/Propulsion Component facilities included in this catalogue have been limited to those used for testing or conducting research on:

- Turbines
- Compressors
- Combustors

In contrast to propulsion wind tunnels and engine test facilities that require large complexes and usually large capital investments, component facilities are smaller, simpler, and considerably less costly. Whereas their larger counterparts are principally used for testing and development of complete propulsion systems, component facilities are most often used for conducting more basic and applied research plus experimental studies on propulsion subsystems. A certain amount of development testing is also performed in them by engine manufacturers.

Of the component facilities listed, U.S. industry owns the major share, followed by NASA and the DOD. Universities own mostly small-scale fundamental research facilities and rigs. The number of foreign facilities included is minimal, with Japan being the only respondent to this survey.

Each of the foregoing subcategories of component facilities is presented separately in the order listed. Individual indices and lists of comparable facilities are included for each, followed by their respective data sheets.

## COMPARABLE CAPABILITIES

Three groups of comparable facilities were established for each of the foregoing subcategories, based on the most appropriate distinguishing technical performance parameter for each, i.e., flow rate (turbines), power level (compressors), and pressure level (combustors). The following table indicates the range used for each of the three groups:

| | Turbines | Compressors | Combustors |
|---|---|---|---|
| | Flow Rate (lb/sec) | Power Level (hp) | Pressure Level (atm) |
| Group A | <50 | <10,000 | <10 |
| Group B | 50-100 | 20-25,000 | 10-30 |
| Group C | >100 | >25,000 | >30 |

Because of the basic similarities among most component facilities, it was extremely difficult to identify individually comparable facilities. Instead, the particular group to which a specific facility has been assigned has been referenced in the Comparable Facilities box of each data sheet, and in the individual subcategory indices.

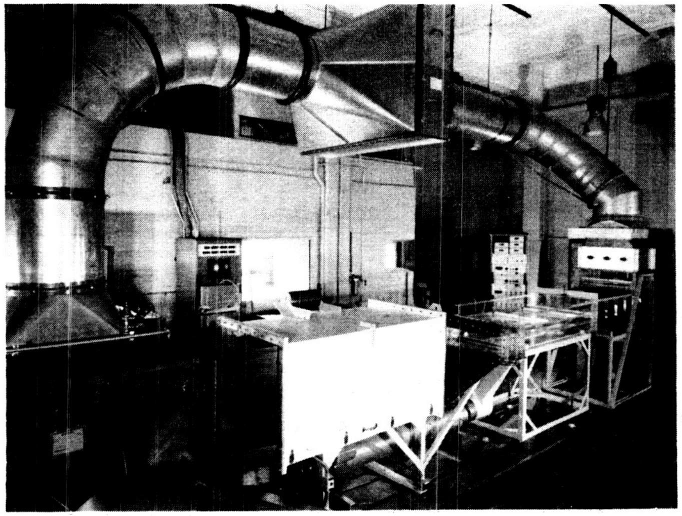
## TURBINE RESEARCH FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) | Group |
|---|---|---|---|---|---|---|---|
| | U.S. NASA | | | | | | |
| | Lewis Research Center | | | | | | |
| 104 | Turbine Heat Transfer Fundamentals Facilities | 7 | N/A | Atmospheric | Atmospheric | N/A | A |
| 105 | Hot Cascade 2D Cascade Facility | 15 | N/A | 2500 | 8 | N/A | A |
| 106 | Small Uncooled Turbine Facilities | 2 ½ | 45 | 150 | 3 ½ | 45 000 | A |
| 107 | Small Warm Turbine Facility | 8 | 1250 | 800 | 8 | 60 000 | A |
| 108 | High-Pressure Turbine Hot Section Facility | 200 | 35 000 | 2500 | 20 | 23 000 | C |
| 109 | Large Warm Turbine Facilities | 25 | 5000 | 950 | 3 | 25 000 | A |
| 110 | Turbomachinery Aerodynamic Laser Anemometer Facility | 10 | N/A | Ambient | Atmospheric | N/A | Unique |
| | U.S. INDUSTRY | | | | | | |
| | Garrett Turbine Engine Company | | | | | | |
| 111 | (Cooled) Hot Turbine and Cascade Test Facility | 22 | 3000 | 2800 | 20 | 43 000 | B |
| 112 | Cold Air Turbine Mapping Facility | 6 | 400 | 600 | 125 psia | 60 000 | A |
| | General Electric | | | | | | |
| 113 | Cell A7 Air Turbine Test Facility | 70 | 15 000 | 100 - 1000 | 8 | 15 000 | B |
| | Pratt & Whitney | | | | | | |
| 114 | X-203 Test Stand | 400; 125 | 10 000 - 20 000 | -50 - +800 | 1.3; 7 atm | 600 - 15 000 | C |
| 115 | X-212 Test Stand | 225; 125; 84 | 4000 - 10 500 | +1200 | 2; 8; 9 atm | 5000 - 15 000 | C |

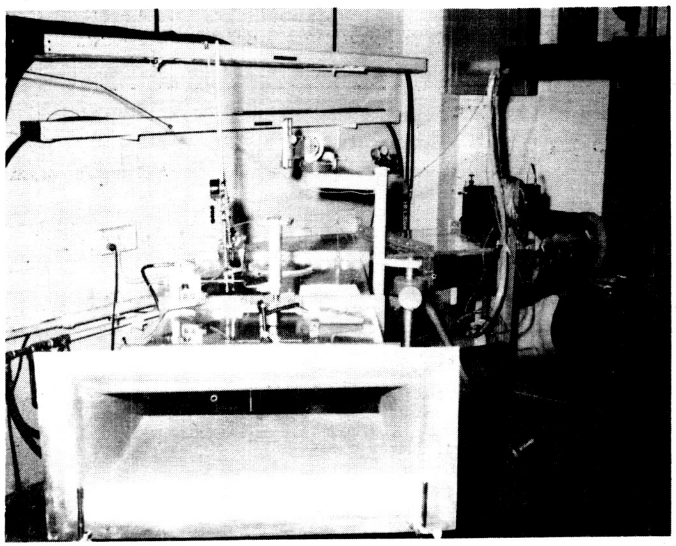
## TURBINE RESEARCH FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. Max) | Speed (rpm) | Group |
|---|---|---|---|---|---|---|---|
| | U.S. INDUSTRY | | | | | | |
| | Telydyne CAE | | | | | | |
| 116 | Hot Cascade Test Stand | 2 | N/A | 3000 | 7 | N/A | A |
| 117 | Turbine 1 and Turbine 2 Cold Flow Rig | 25 | 300; 2400; 450 | Ambient - 300 | 1.7 | 45 000; 23 000; 11 500 | A |
| | Westinghouse Combustion Turbine Systems | | | | | | |
| 118 | Vane Cooling Development Rig | 90 | N/A | 2200 | 20 | N/A | B |
| 119 | Aerodynamic Cascade Test Rig Row One Turbine Vane | 90 | N/A | 900 | 8 | N/A | B |
| | U.S. UNIVERSITY | | | | | | |
| | Massachusetts Institute of Technology | | | | | | |
| 120 | Blowdown Turbine Facility | 64<br>200 scaled | 2000<br>52 000 scaled | 500<br>4000 scaled | 10<br>40 scaled | 7000<br>14 000 scaled | B |
| | JAPAN | | | | | | |
| | Ihi Mizuho Plant | | | | | | |
| 121 | High-Pressure Turbine Facility (HPT) | 40 | 6000 | 2500 | 3.5 | 15 000 | A |
| | National Aerospace Laboratory | | | | | | |
| 122 | High-Temperature Turbine Cooling Facility | 3.7 | N/A | 2200 | 9 | N/A | A |

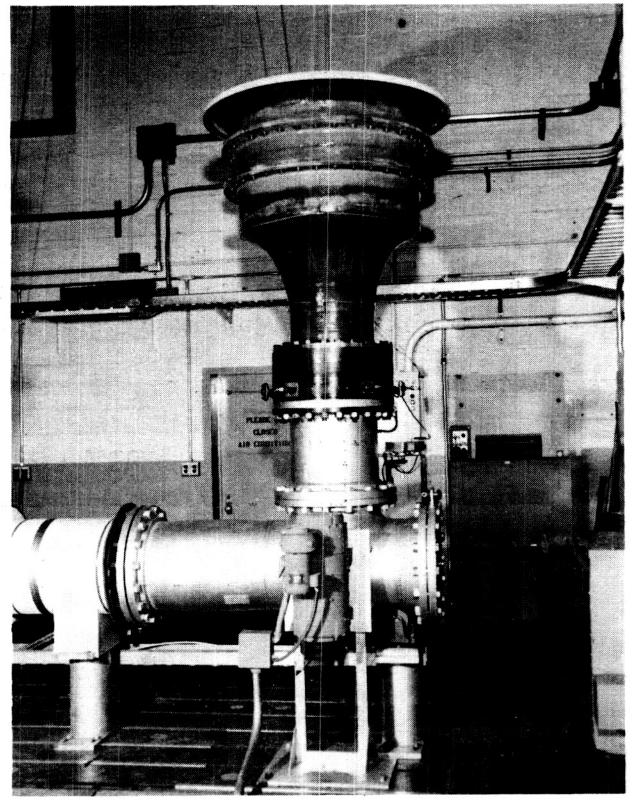
# TURBINE HEAT TRANSFER FUNDAMENTALS FACILITIES



BOUNDARY LAYER
TRANSITION TUNNEL



TYPICAL FLOW VISUALIZATION TUNNEL



ROTOR WAKE HEAT TRANSFER RIG

| NASA–Lewis Research Center Cleveland, OH | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 6 x 27 cross section | **MAX. FLOW RATE: (lb/sec)** 7 | Most major engine companies have comparable facilities. |
| | **DATE BUILT/UPGRADED:** 1979–1983 | **PRESSURE LEVEL: (atm. max.)** Atmospheric | |
| Turbine Heat Transfer Fundamentals Facilities | **REPLACEMENT COST:** $1000K | **INLET TEMP. RANGE: (°F)** Atmospheric | |
| | **OPERATIONAL STATUS:** 1 test run per week average | **SPEED RANGE: (rpm)** N/A | |
| | | **POWER LEVEL: (hp)** N/A | |
| | Open-loop tunnels, facilities complex consisting of 7 test rigs in 4 separate test cells (CW-7, SW-2, SW-6, W-5A) | | |

TESTING CAPABILITIES: This facility complex consists primarily of open-loop wind tunnels drawing room air into the altitude exhaust system. There is one closed-loop tunnel and a closed-loop water tunnel. Detailed measurements of temperatures, pressures, and surface heat fluxes are made. Velocity and turbulence surveys are made throughout the flow field. Approximately 120 data channels are available.

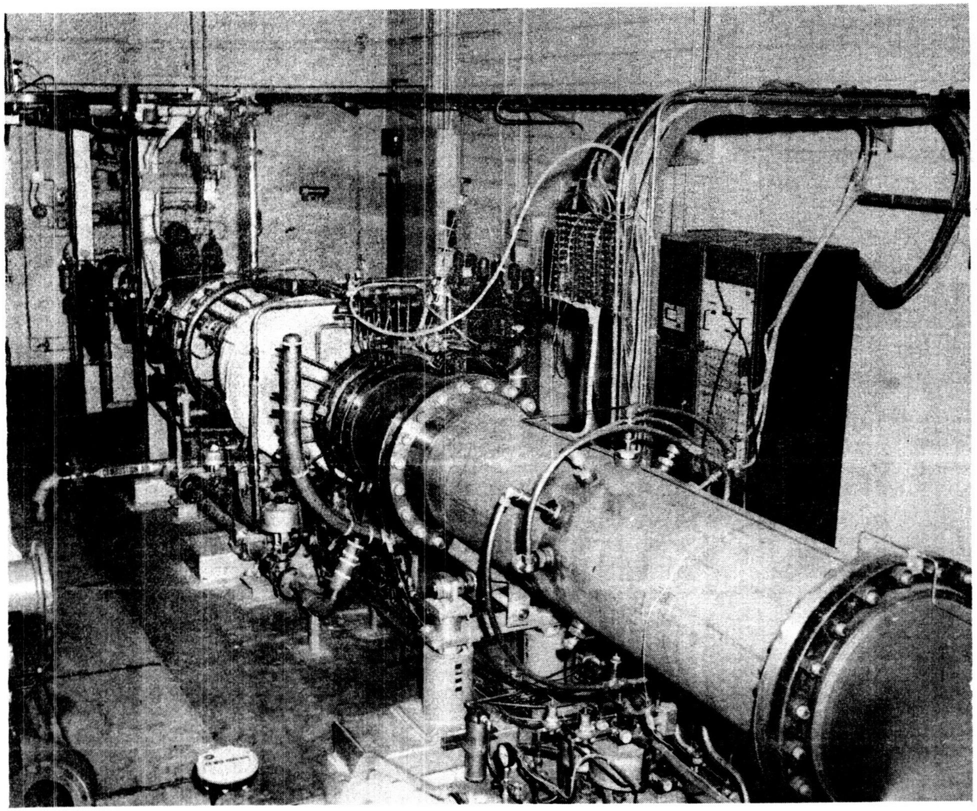
DATA ACQUISITION: Research data points are recorded by means of a central data collector system (ESCORT II) and are processed on the IBM 370 computer for control room display or post-test analysis.

CURRENT PROGRAMS: Studies of fundamental heat transfer mechanisms in stagnation, transition, wake, and film-cooling regions with the objective of developing analytic models. (SW-6 inactive.)

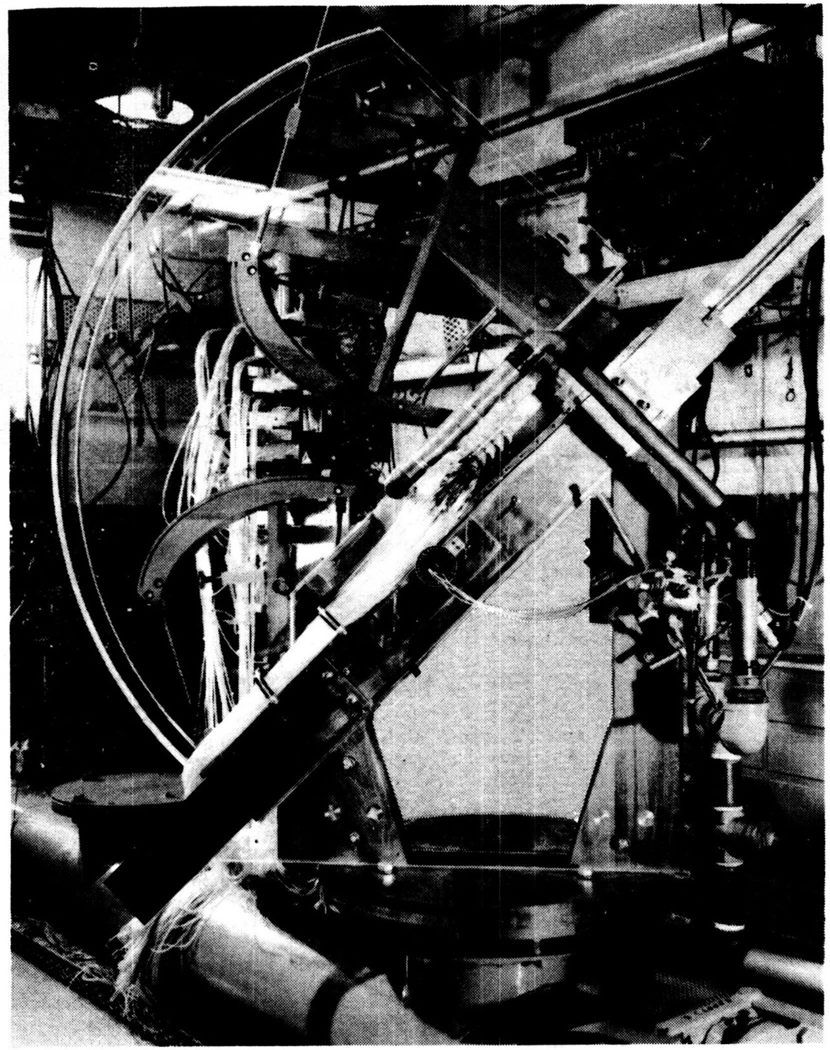
PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities and Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities and Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# HOT TURBINE 2-D CASCADE FACILITIES



HOT CASADE IN W-G FACILITY



2-D AMBIENT TEMPERATURE

| NASA–Lewis Research Center, Cleveland, OH | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 3.5 Vane Hgt x 12 W | **MAX. FLOW RATE: (lb/sec)** 15 | Most major engine companies have comparable facilities. |
| | **DATE BUILT/UPGRADED:** 1965 | **PRESSURE LEVEL: (atm. max.)** 8 | |
| Hot Turbine 2D Cascade Facility | **REPLACEMENT COST:** $1M | **INLET TEMP. RANGE: (°F)** 2500 | |
| | **OPERATIONAL STATUS:** Inactive as Cascade; as Flat Plate Facility, 1 shift per week/1 shift per day | **SPEED RANGE: (rpm)** N/A<br>**POWER LEVEL: (hp)** N/A | |
| | Cooled turbine vane cascade | | |

TESTING CAPABILITIES: Facility combustor provides 2500°F vane inlet gas temperature. Large-scale and extensive instrumentation channels allow detailed and precise measurements of vane surface and gas stream temperatures and pressures in a vane passage that closely simulates actual conditions typical of advanced engines.

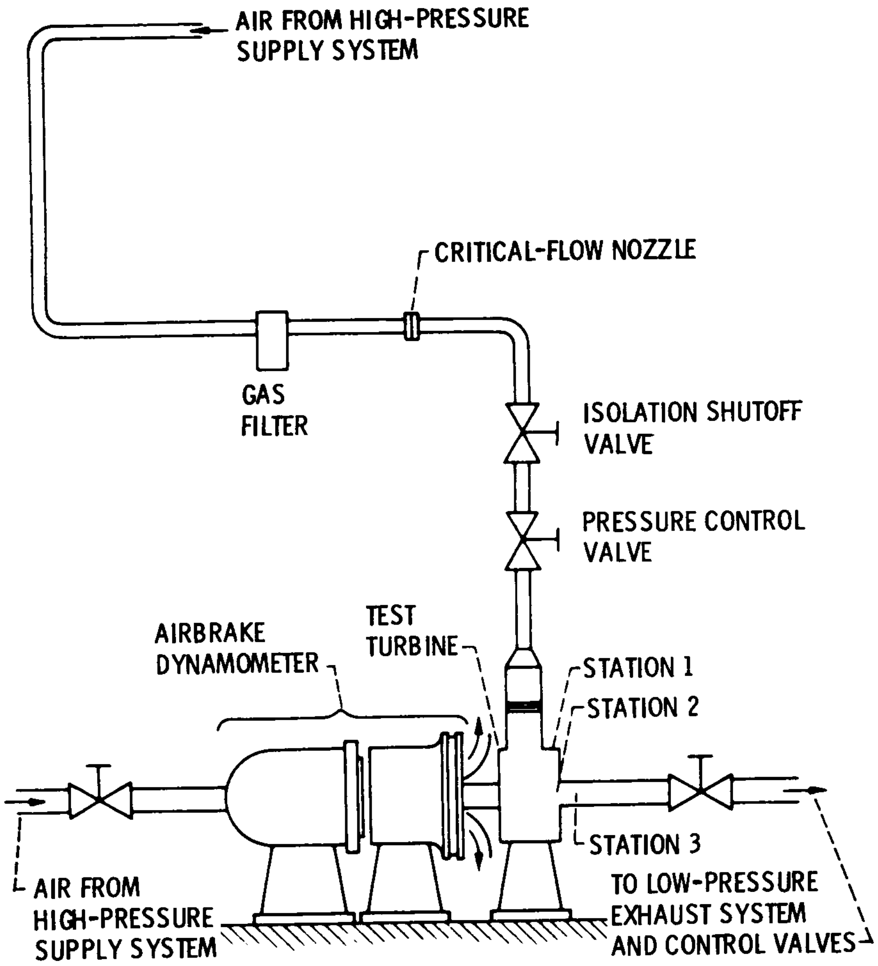
DATA ACQUISITION: Research data points are recorded by means of a central data collector system (ESCORT II) and are processed on the central IBM 370 computer for control room display or post-test analysis.

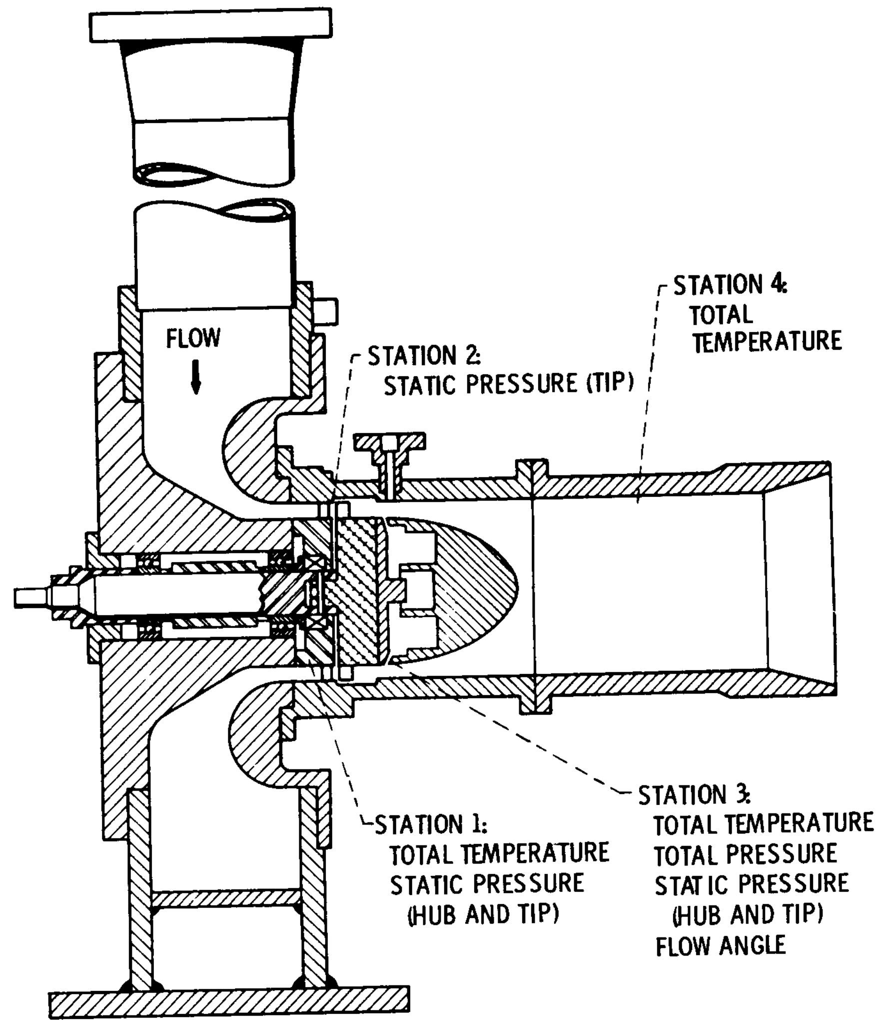
CURRENT PROGRAMS: Development of advanced high-temperature instrumentation. Studies of the interactive effects of airfoil geometry, curvature, temperature level, and turbulence level on turbine heat transfer.

PLANNED IMPROVEMENTS: Updating of test section planned to provide increased data resolution.

LOCAL INFORMATION CONTACT: Lawrence E. Macioce, Research Experiments Branch, (216) 433-4000, ext. 6884.

# SMALL UNCODED TURBINE FACILITIES



| | | | |
|---|---|---|---|
| NASA–Lewis Research Center, Cleveland, OH | **TURBINE COMPONENT RESEARCH FACILITY** | | **COMPARABLE FACILITIES** |
| | **COMPONENT SIZE: (in)** 5 dia | **MAX. FLOW RATE: (lb/sec)** 2½ | Group A |
| | **DATE BUILT/UPGRADED:** | **PRESSURE LEVEL: (atm. max.)** 3½ | |
| Small Uncooled Turbine Facilities | **REPLACEMENT COST:** | **INLET TEMP. RANGE: (°F)** 150 | |
| | **OPERATIONAL STATUS:** 1 shift per day | **SPEED RANGE: (rpm)** 45 000 | |
| | | **POWER LEVEL: (hp)** 45 | |
| | Small axial and centrifugal turbines | | |

TESTING CAPABILITIES: This facility complex provides the capability of evaluating aerodynamic performance losses of small uncooled axial and centrifugal turbines. Traversing probes at the rotor exit provide the capability of obtaining temperature and pressure measurements. Torque measurements are made at the power absorber, thus enabling the generation of complete performance maps. Approximately 100 data channels are available.

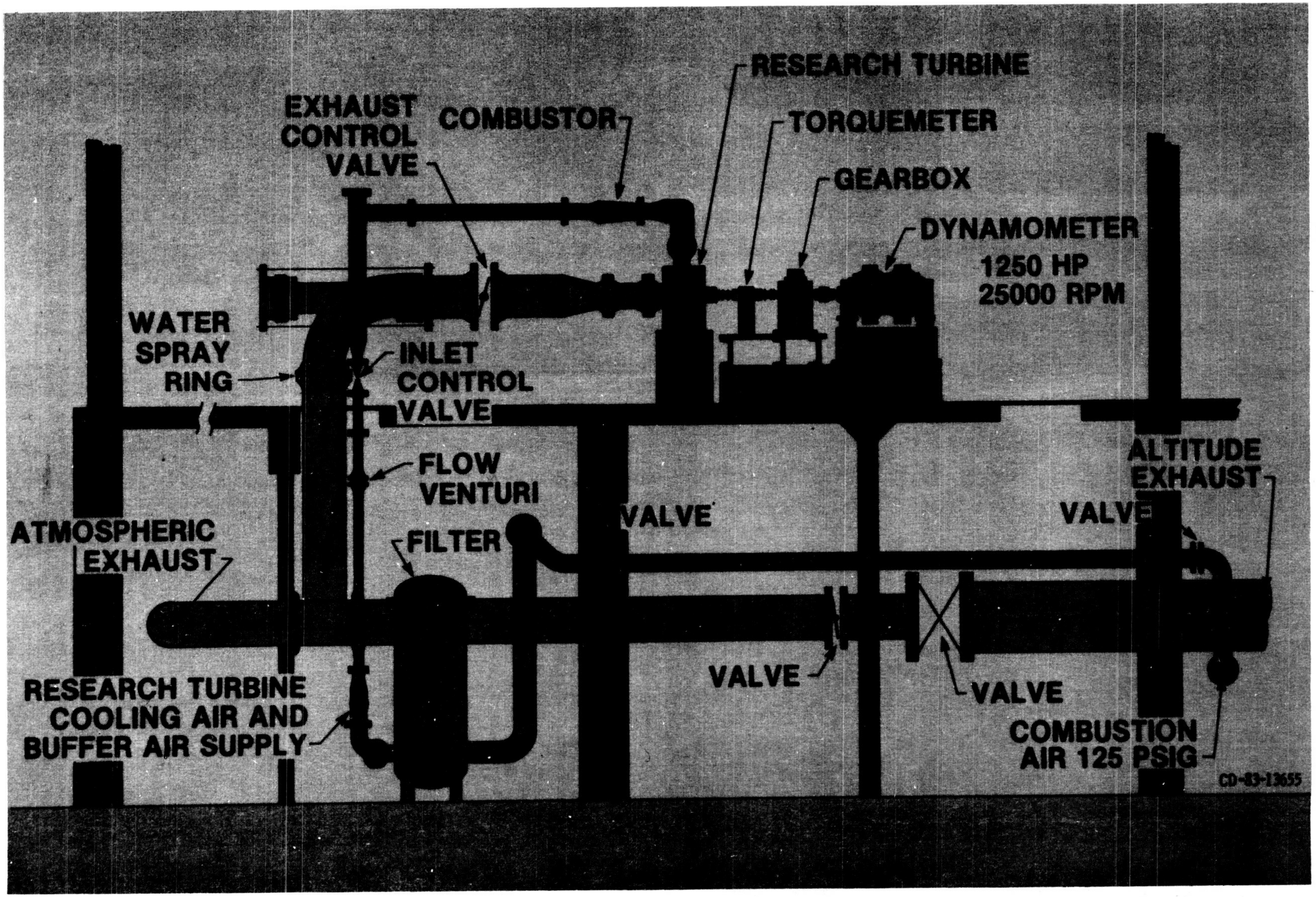
DATA ACQUISITION: Research data points are recorded by means of a central data collector system (ESCORT II) and are processed on the IBM 370 computer for control room display or post-test analysis.

CURRENT PROGRAMS: Studies of innovative design concepts, clearance, and size effects.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Lawrence E. Macioce, Research Experiments Branch, (216) 433-4000, ext. 6884, FTS 8-294-6884; Louis A. Povinelli, Turbine Aerodynamics Section, (216) 433-4000, ext. 5212, FTS 8-294-5212.

# SMALL WARM TURBINE TEST FACILITY



| NASA–Lewis Research Center, Cleveland, OH | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 14 dia max | **MAX. FLOW RATE: (lb/sec)** 8 | Group A |
| | **DATE BUILT/UPGRADED:** Scheduled for 1986 | **PRESSURE LEVEL: (atm. max.)** 8 | |
| Small Warm Turbine Facility | **REPLACEMENT COST:** $4M | **INLET TEMP. RANGE: (°F)** 800 | |
| | **OPERATIONAL STATUS:** Operational 1986 | **SPEED RANGE: (rpm)** 60 000 | |
| | | **POWER LEVEL: (hp)** 1250 | |
| | Small axial- and radial-type turbines | | |

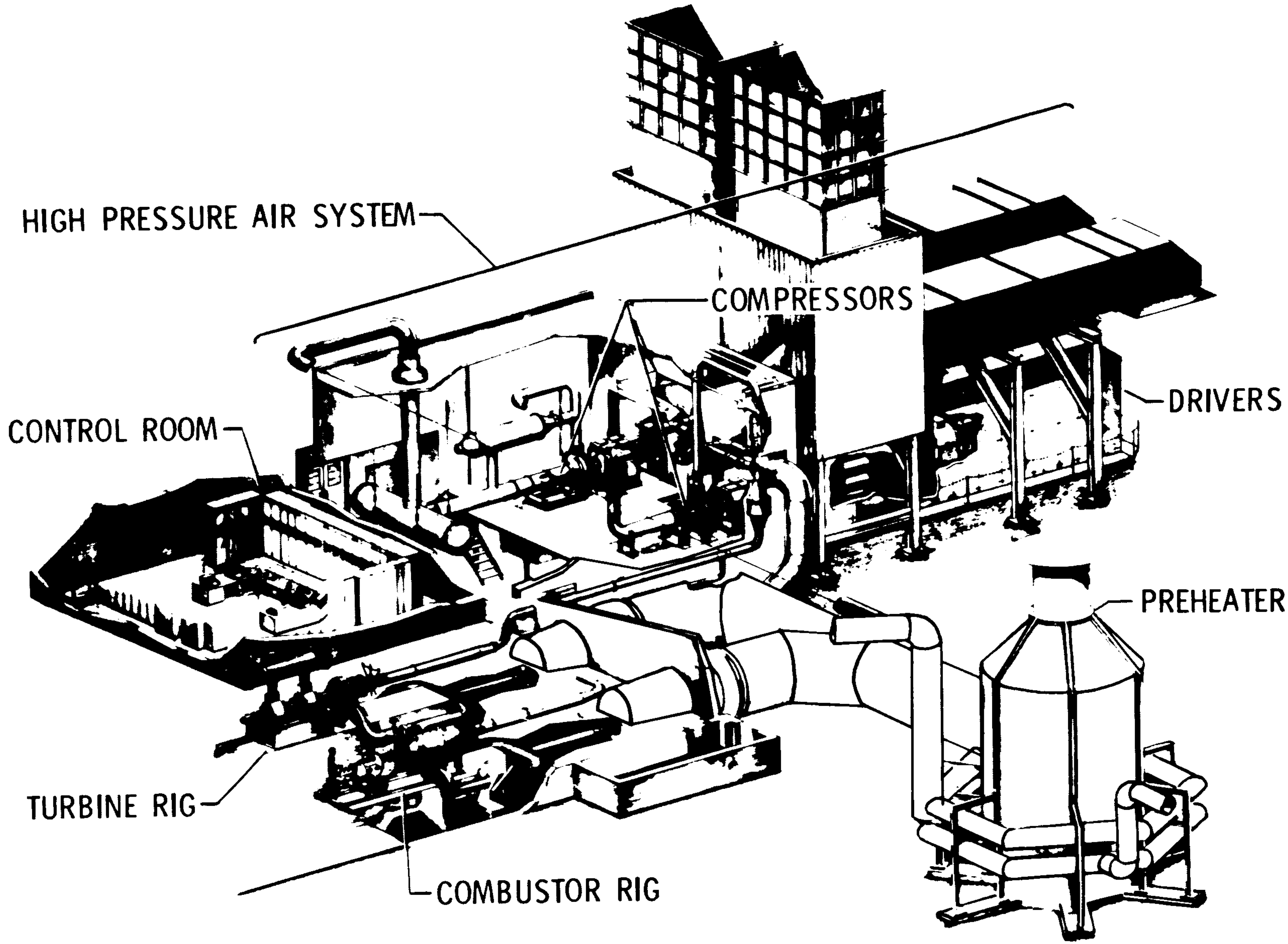
TESTING CAPABILITIES: This facility provides the capability of examining the impact of turbine cooling on the aerodynamic performance of small turbine concepts at actual engine hot-gas primary flow to turbine coolant flow ratios. Extensive data channel capability exists for measuring research parameters such as temperature, pressure, and flows, including 72 channels of rotating measurements.

DATA ACQUISITION: Research data points are recorded by means of a central data collector system (ESCORT II) and are processed on the IBM 370 computer for control room display or post-test analysis.

CURRENT PROGRAMS: Initial Programs: Aerodynamic evaluation of high-work, high-temperature advanced turbine concept.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Lawrence E. Macioce, Research Experiments Branch, (216) 433-4000, ext. 6884, FTS 8-294-6884; Louis A. Povinelli, Turbine Aerodynamics Section, (216) 433-4000, ext. 5212, FTS 8-294-5212.


HIGH PRESSURE AIR SYSTEM
COMPRESSORS
DRIVERS
CONTROL ROOM
PREHEATER
TURBINE RIG
COMBUSTOR RIG

| | | | |
|---|---|---|---|
| NASA–Lewis Research Center, Cleveland, OH | **TURBINE COMPONENT RESEARCH FACILITY** | | **COMPARABLE FACILITIES** |
| | **COMPONENT SIZE:** 15 – 30 **(in)** | **MAX. FLOW RATE:** 200 **(lb/sec)** | None |
| | **DATE BUILT/UPGRADED:** 1980 | **PRESSURE LEVEL:** 20 **(atm. max.)** | |
| High-Pressure Turbine Hot Section Facility | **REPLACEMENT COST:** $15M | **INLET TEMP. RANGE:** 2500 **(°F)** | |
| | **OPERATIONAL STATUS:** Inactive | **SPEED RANGE:** 23 000 **(rpm)** | |
| | | **POWER LEVEL:** 35 000 **(hp)** | |
| | Utilizes dedicated boost compressors to raise pressure and temperature level of existing 10-atm, 500°F central air supply system. Shares supply system with High Pressure Combustor Facility. | | |

TESTING CAPABILITIES: This facility provides the capability of making a large number of precise research measurements in a real engine environment of temperature, pressure, speed, and airflow. Operation over a wide range of conditions is provided by fully automated digital control of 12 control loops, including speed, inlet temperature, and pressure; airflow; and cooling airflow. Stationary and rotating blade metal temperatures, pressure, and heat-flux measurements (500 data channels total, 80 channels rotating data). Fully automated facility control and data acquisition is achieved through five dedicated PDP-11 minicomputers affording precise setting of operating conditions and data replication.

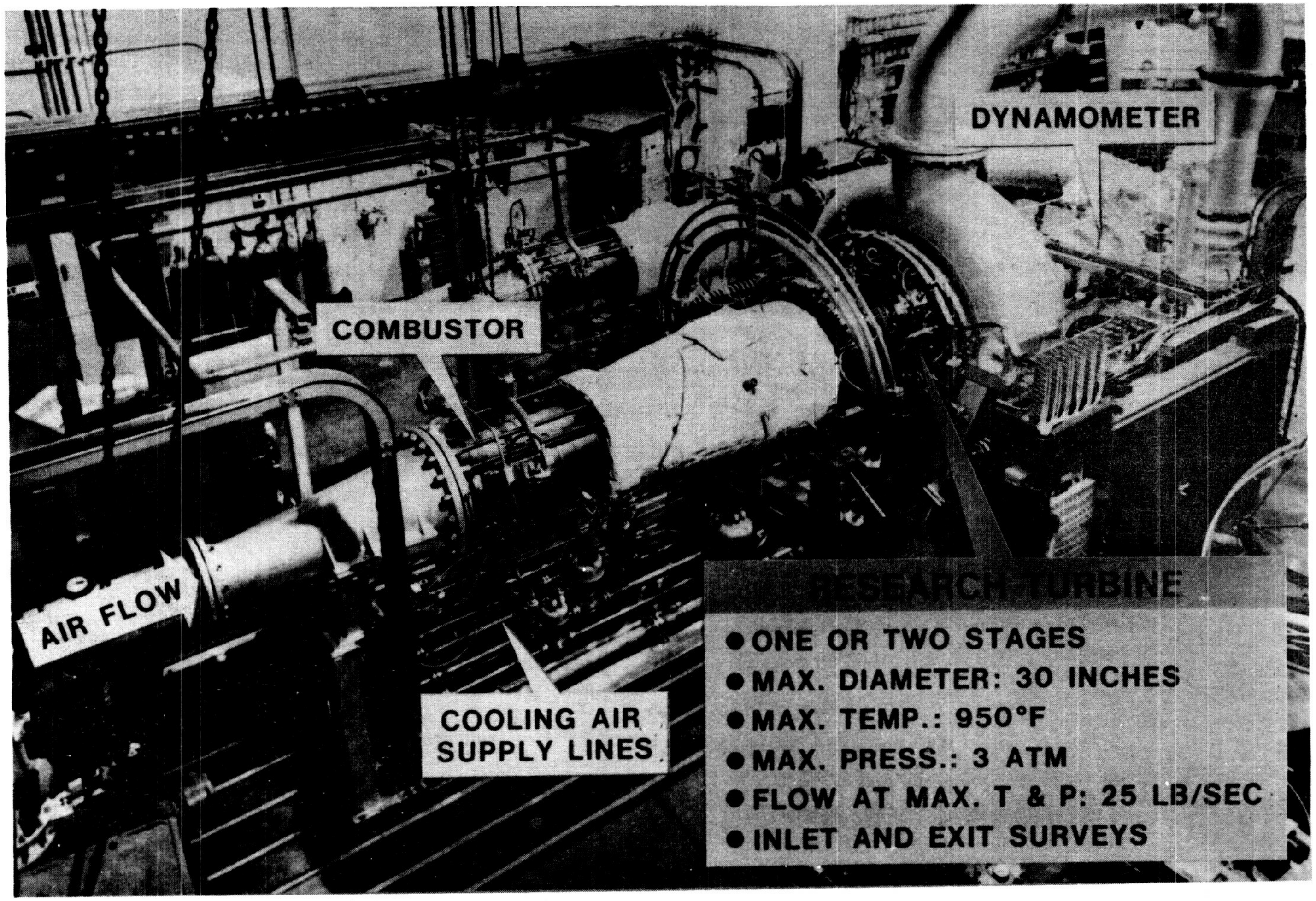
DATA ACQUISITION: Research data points are recorded automatically in the central data collector system (ESCORT II) and are processed on the central IBM 370 computer for control room display or post-test analysis.

CURRENT PROGRAMS: Obtaining research data in support of the Turbine Engine Hot Section Technology (HOST) Program.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# WARM TURBINE RESEARCH FACILITY



| NASA–Lewis Research Center, Cleveland, OH | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 30 dia max | **MAX. FLOW RATE: (lb/sec)** 25 | Group A |
| | **DATE BUILT/UPGRADED:** 1965/1977-79 | **PRESSURE LEVEL: (atm. max.)** 3 | |
| Large Warm Turbine Facilities | **REPLACEMENT COST:** $5M | **INLET TEMP. RANGE: (°F)** 950 | |
| | **OPERATIONAL STATUS:** Inactive | **SPEED RANGE: (rpm)** 25 000 | |
| | | **POWER LEVEL: (hp)** 5000 | |
| | Cooled-core axial flow turbine | | |

TESTING CAPABILITIES: These facilities provide the capability of evaluating the impact of turbine cooling on aerodynamic losses of advanced turbine concepts. Tests are conducted in full annular cascades or rotating turbine stages at primary air to coolant temperature ratios, which are representative of those encountered in actual high-temperature engines. Approximately 400 data channels are available for the measurements of temperature, pressure, primary and cooling airflow rates, speed, and torque, 72 channels of which are available for pressure and temperature measurements on the rotating blades. An LOV system for detailed mapping of flow is being developed for flow analysis code development and verification.

DATA ACQUISITION: Research data points are recorded by means of a central collector system (ESCORT II) and are processed on the IBM 370 computer for control room display or post-test analysis.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

| NASA–Lewis Research Center, Cleveland, OH | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 20 OD, 17 ID Annular Cascade | **MAX. FLOW RATE: (lb/sec)** 10 | None |
| | **DATE BUILT/UPGRADED:** 1973/1976/1983 | **PRESSURE LEVEL: (atm. max.)** Atmospheric | |
| Turbomachinery Aerodynamic Laser Anemometer Facility | **REPLACEMENT COST:** $250K | **INLET TEMP. RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** 1 test run per week | **SPEED RANGE: (rpm)** N/A | |
| | | **POWER LEVEL: (hp)** N/A | |
| | Laser velocity research, facility located in W-6 | | |

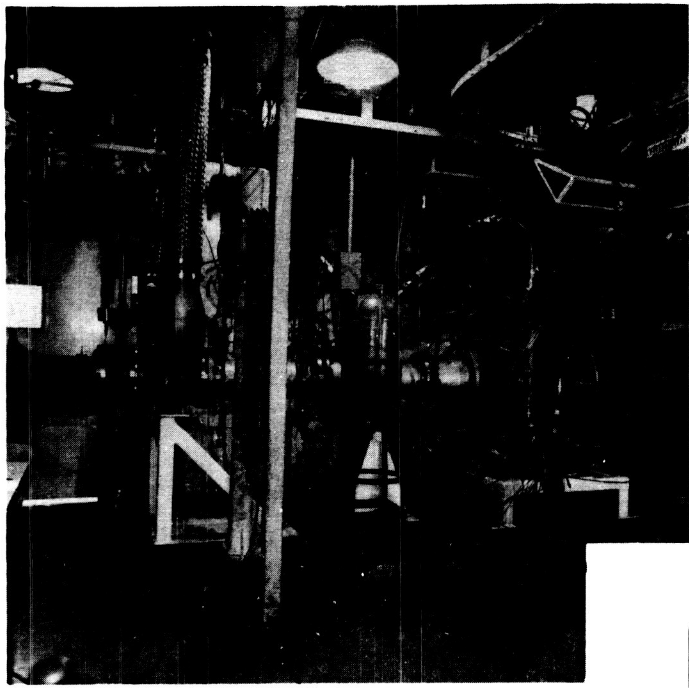
TESTING CAPABILITIES: This facility provides a test vehicle for state-of-the-art research on laser anemometry as applied to measurements within turbomachinery. The actual size turbine hardware operating at design Mach numbers provides one of the unique capabilities of this facility. One goal of the laser research is to provide a nonintrusive three-component measurement of the velocity field within the stator for use in the verification of three-dimensional computer codes. Conventional instrumentation is also available for comparison.

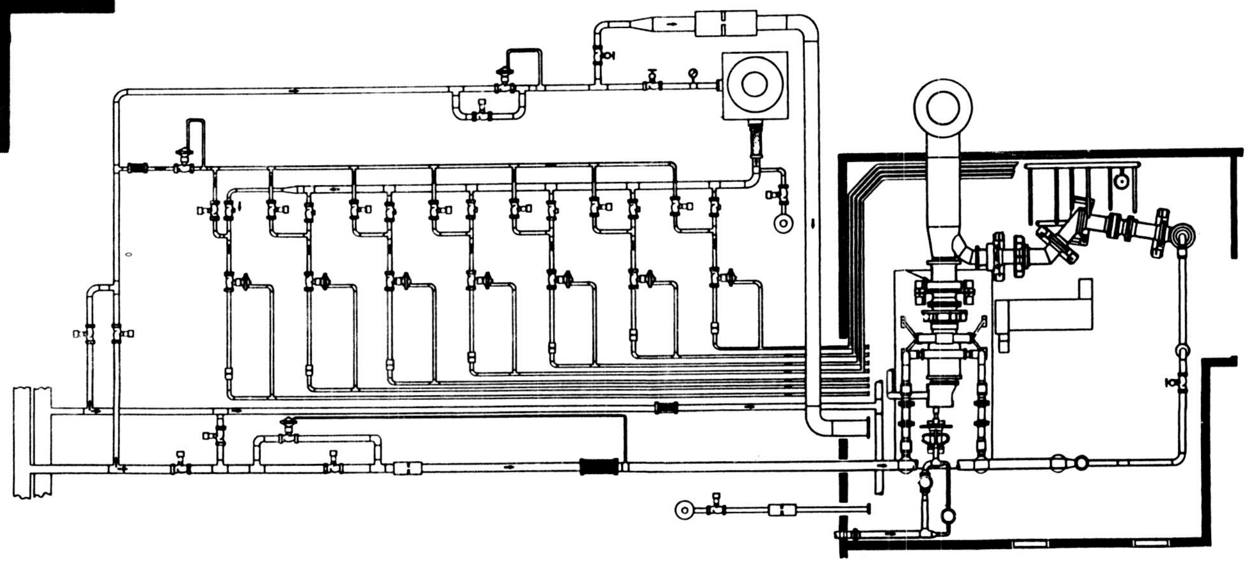
DATA ACQUISITION: Research data are recorded by a dedicated Digital Corporation microcomputer which is also used to control the precision laser anemometer six-axis positioning system. High-speed data transmission by video cable is planned for the more time-consuming data analysis.

CURRENT PROGRAMS: Research on a combined fringe and interferometer laser anemometer for three velocity component measurements for single optical access situations that occur in turbomachinery.

PLANNED IMPROVEMENTS: Turbulence level and boundary layer control within cascade. Use of faster optics and smaller probe volume for the laser anemometer for better accuracy measurements near surfaces.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.





| Garrett Turbine Engine Company, Phoenix, AZ | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** 18 dia **(in)** | **MAX. FLOW RATE:** 22 **(lb/sec)** | Group B |
| | **DATE BUILT/UPGRADED:** 1967 continually upgraded | **PRESSURE LEVEL:** 20 **(atm. max.)** | |
| (Cooled) Hot Turbine and Cascade Test Facility | **REPLACEMENT COST:** $1M | **INLET TEMP. RANGE:** 2800 **(°F)** | |
| | **OPERATIONAL STATUS:** 1 – 2 shifts per day | **SPEED RANGE:** 43 000 **(rpm)** | |
| | | **POWER LEVEL:** 3000 **(hp)** | |

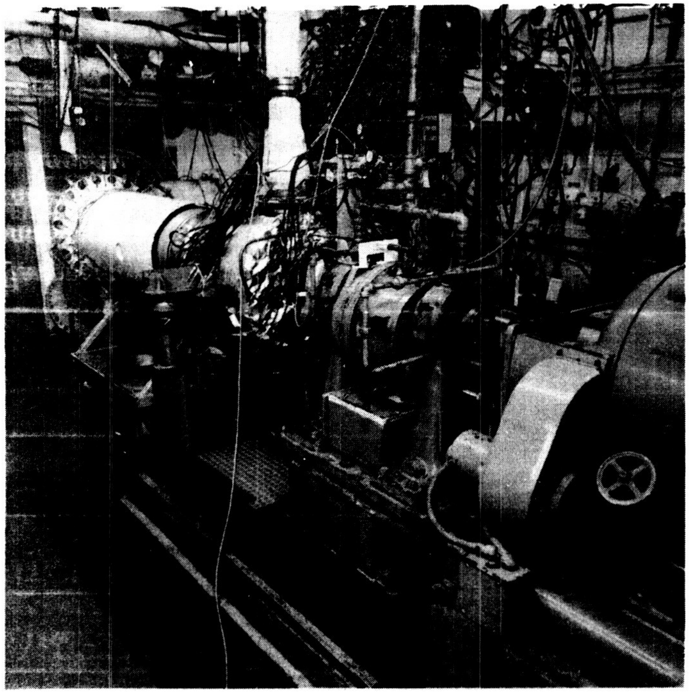
TESTING CAPABILITIES: This facility provides versatile capability for aerothermodynamic testing of axial and radial turbines and stationary cascades for research, development, and product improvement. Capabilities include heat-transfer testing of static and rotating components, regenerator efficiency testing, core engine tests, afterburner tests, and high-temperature tests of rotating components. Both gaseous and liquid fuels are available. Nonvitiated air supplies to 2000°F are available.

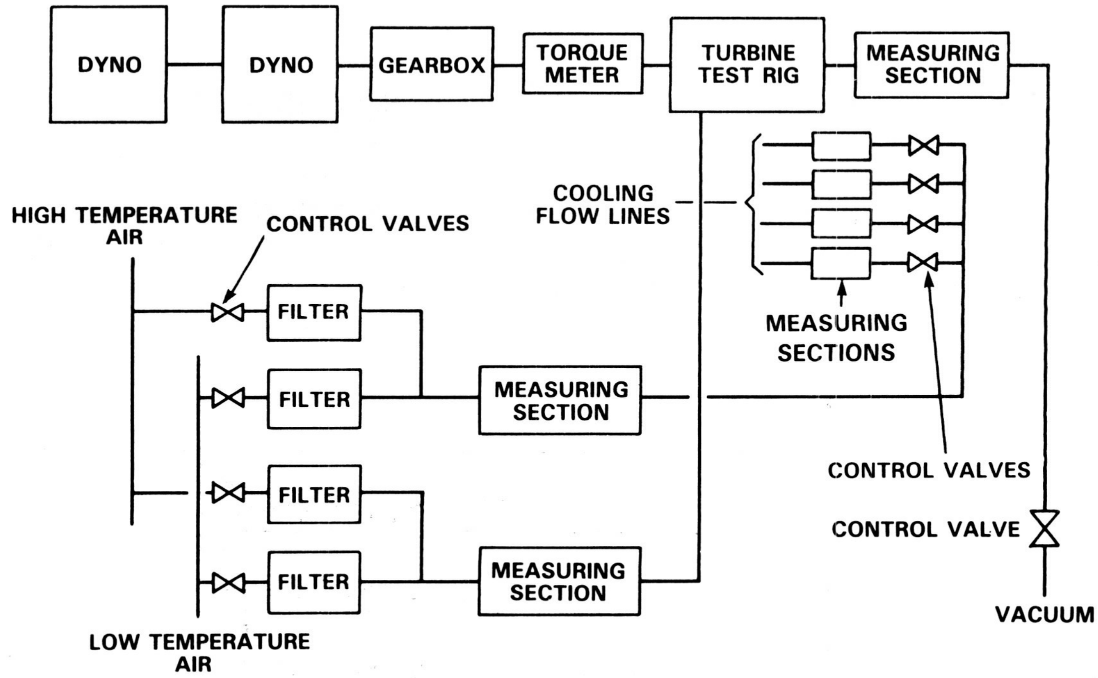
DATA ACQUISITION: Data are recorded by computer via the central data acquisition system. "On-line" performance calculations are provided at the test cell on CRT.

CURRENT PROGRAMS: Development and research "hot section" programs.

PLANNED IMPROVEMENTS: Continual update.

LOCAL INFORMATION CONTACT: Robert L. Olive, Engineering Laboratory, (602) 231-4913.




DYNO
DYNO
GEARBOX
TORQUE METER
TURBINE TEST RIG
MEASURING SECTION
COOLING FLOW LINES
MEASURING SECTIONS
CONTROL VALVES
CONTROL VALVE
VACUUM
HIGH TEMPERATURE AIR
CONTROL VALVES
FILTER
FILTER
FILTER
FILTER
MEASURING SECTION
MEASURING SECTION
LOW TEMPERATURE AIR

| Garrett Turbine Engine Company, Phoenix, AZ<br><br>Cold Air Turbine Mapping Facility | **TURBINE COMPONENT RESEARCH FACILITY** | | **COMPARABLE FACILITIES** |
|---|---|---|---|
| Garrett Turbine Engine Company, Phoenix, AZ | **COMPONENT SIZE:** 30 dia<br>**(in)** | **MAX. FLOW RATE:** 6<br>**(lb/sec)** | Group A |
| | **DATE BUILT/UPGRADED:** 1960<br>continually upgraded | **PRESSURE LEVEL:** 125 psia<br>**(atm. max.)** | |
| Cold Air Turbine Mapping Facility | **REPLACEMENT COST:** $700K | **INLET TEMP. RANGE:** 600<br>**(°F)** | |
| | **OPERATIONAL STATUS:**<br>1 to 2 shifts per day | **SPEED RANGE:** 60 000<br>**(rpm)** | |
| | | **POWER LEVEL:** 400<br>**(hp)** | |
| | | | |

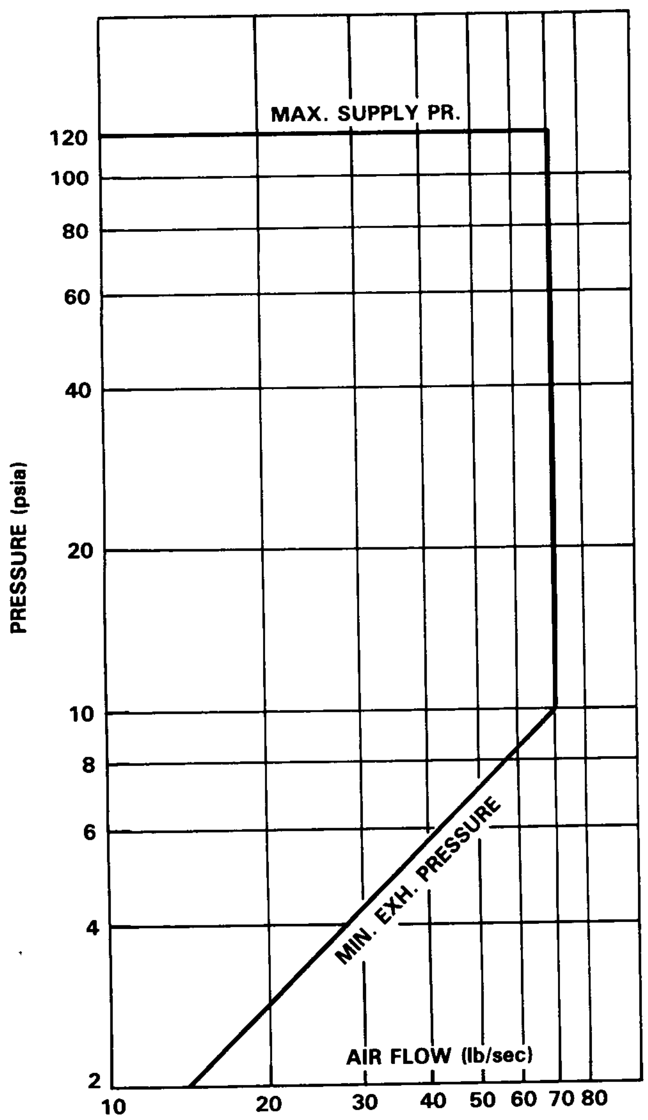
TESTING CAPABILITIES: This facility provides the capability for aerothermodynamic scaled testing of axial and centrifugal turbines for research, development, and product improvement. Capabilities include measurement of cooling flow effects, controlled cooling flow rates, axial and radial clearances, and rotating pressures and temperatures, plus standard performance measurements. High-resolution torque meters provide torque measurements to 9000 in-lb. Power absorption by electric dynamometer.

DATA ACQUISITION: Data are recorded by computer via the central data acquisition system. "On-line" performance calculations are provided at the test cell on CRT.

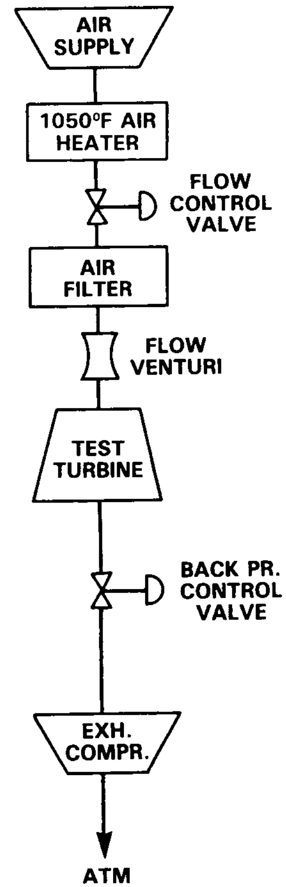
CURRENT PROGRAMS: High- and low-pressure turbine programs.

PLANNED IMPROVEMENTS: Continual update.

LOCAL INFORMATION CONTACT: Robert L. Olive, Engineering Laboratory, (602) 231-4913.




CELL A7 PERFORMANCE CHART




CELL A7 SCHEMATIC

| General Electric Company, Cincinnati, OH | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** **(in)** Turbine discharge dia 42 max | **MAX. FLOW RATE:** 70 **(lb/sec)** | Group B |
| | **DATE BUILT/UPGRADED:** 1953/1964/1972 | **PRESSURE LEVEL:** 8 **(atm. max.)** | |
| Cell A7 Air Turbine Test Facility | **REPLACEMENT COST:** | **INLET TEMP. RANGE:** 100 – 1000 **(°F)** | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE:** 15 000 **(rpm)** | |
| | | **POWER LEVEL:** 15 000 **(hp)** | |

TESTING CAPABILITIES: When necessary, the multistage low-pressure turbine diameter is scaled so that the discharge flow function is no larger than 125 $(lb/sec\sqrt{deg}/(psia)$. The discharge diameter cannot exceed 42 inches. High-pressure turbines are usually tested in full-scale size, using the necessary cooling air/primary air temperature ratio and flow ratios. Using 100°F cooling air, the required maximum inlet temperature is nominally 1000°F.

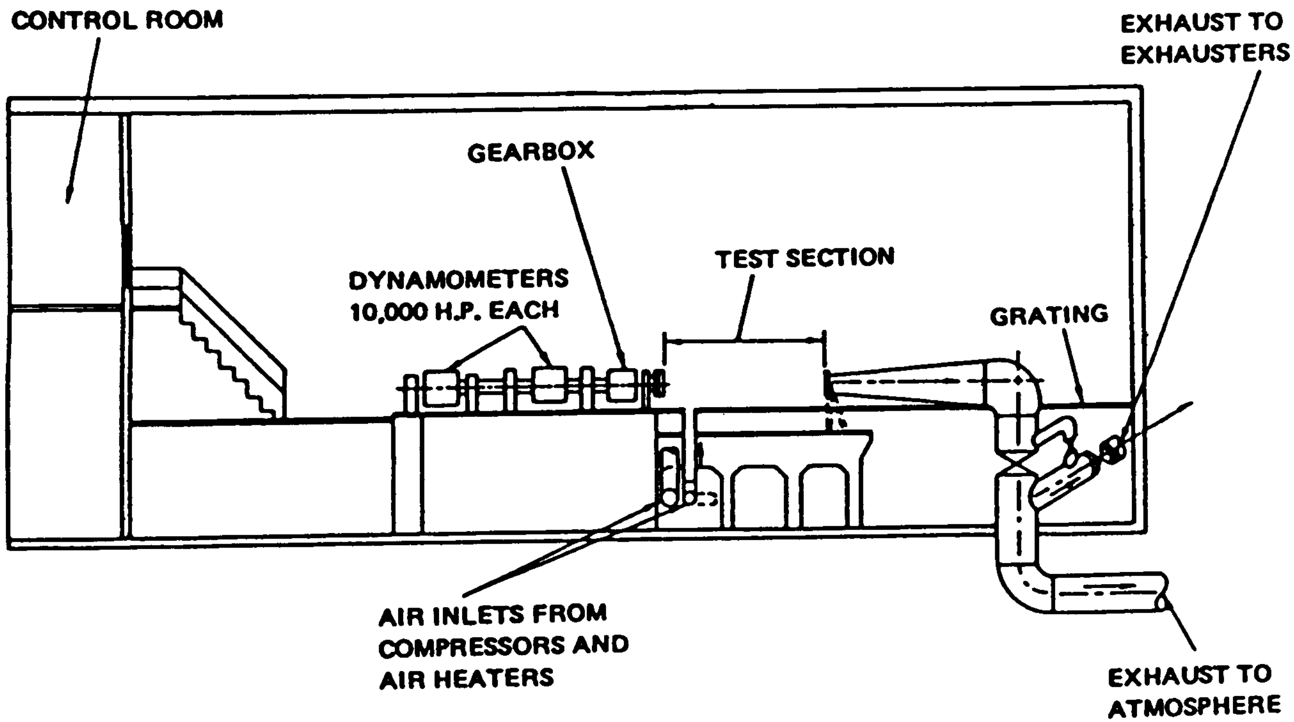
DATA ACQUISITION: 1000+ parameters.

CURRENT PROGRAMS: Efficiency improvement of hp and lp turbines.

PLANNED IMPROVEMENTS: Cell A7 is designed for future modification so that it can test dual rotor turbines at various rpm ratios.

LOCAL INFORMATION CONTACT: W. T. Martin, H70, General Electric Company, Cincinnati, OH 45215, (513) 243-3304/6848.

# X-203 TEST STAND
# WILLGOOS LABORATORY



| | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| United Technologies Pratt & Whitney Aircraft | **COMPONENT SIZE:** Bedplate 32'L x 9'W Centerline 7' – 3" | **MAX. FLOW RATE: (lb/sec)** 400/125 | Group C |
| | **DATE BUILT/UPGRADED:** 1950 | **PRESSURE LEVEL: (atm. max.)** 1.3/7 atm | |
| X-203 Test Stand | **REPLACEMENT COST:** $9M | **INLET TEMP. RANGE: (°F)** -50 – +800 | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE: (rpm)** 600 – 15 000 | |
| | | **POWER LEVEL: (hp)** 10 000 – 20 000 | |
| | Dynamometer Type – Full-scale turbine components | | |

TESTING CAPABILITIES: X-203 stand is a dynamometer test facility presently set up for testing full-scale turbine component rigs, but with the basic capability of being converted to test full-scale turboprop or industrial free turbine engines requiring rotational power absorption. The stand ducting makes use of the laboratory services of high- and low-pressure compressed air, heated air, refrigerated air, and exhaust vacuum.

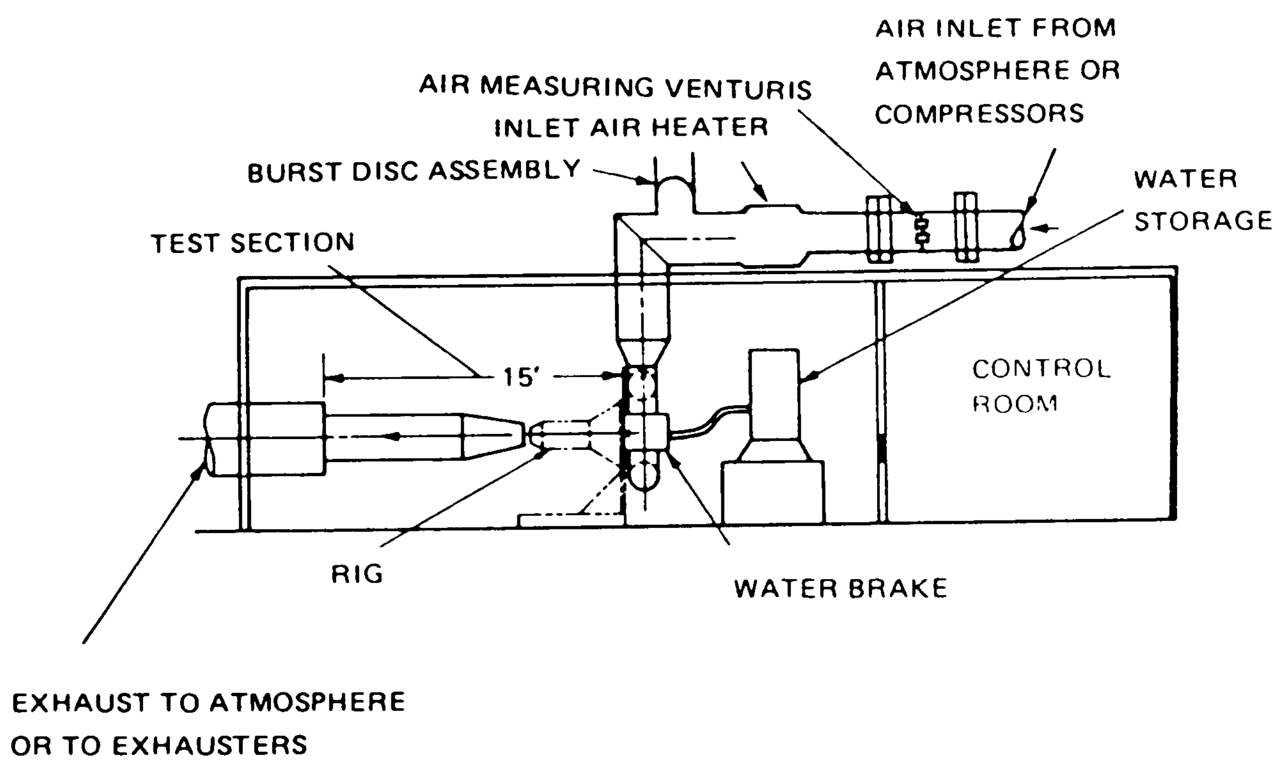
DATA ACQUISITION: Test data are automatically transmitted to the Sigma 8 computer. Computed data are returned within 3 minutes and displayed on an alphanumeric scope. A total of 999 channels are available, 634 pressures, 360 temperatures, and 6 frequencies.

CURRENT PROGRAMS: Full-scale turbine component (research and development).

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Joseph A. Barlock, Manager, Experimental Test Equipment Engineering, East Hartford, CT, (203) 565-2091.

# X-212 TEST STAND
# WILLGOOS LABORATORY



| United Technologies, Pratt & Whitney Aircraft | TURBINE COMPONENT RESEARCH FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** Bedplate 14'L x 9'W Centerline 5' – 6" | **MAX. FLOW RATE (lb/sec):** 225/125/84 | Group C |
| | **DATE BUILT/UPGRADED:** 1957 | **PRESSURE LEVEL (atm. max.):** 2/8/9 | |
| X-212 Test Stand | **REPLACEMENT COST:** $5M | **INLET TEMP. RANGE (°F):** +1200°F | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE (rpm):** 5000 – 15 000 | |
| | | **POWER LEVEL (hp):** 4000 – 10 500 | |
| | Dynamometer Type – Water Brake | | |

TESTING CAPABILITIES: X-212 stand is a dynamometer test facility presently set up for testing either full-scale turbine engine component rigs or scaled research turbine rigs. The stand ducting makes use of the laboratory services of high- and low-pressure compressed air, heated air, and exhaust vacuum.

DATA ACQUISITION: Test data are automatically transmitted to a Univac computer. Computed data are returned within 3 minutes and displayed on an alphanumeric scope. A total of 999 channels are available, 634 pressures, 360 temperatures, and 6 frequencies.

CURRENT PROGRAMS: Scaled research turbine component.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Joseph A. Barlock, Manager, Experimental Test Equipment Engineering, East Hartford, CT, (203) 565-2091.

| Teledyne CAE | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** **(in)** | **MAX. FLOW RATE:** 2 **(lb/sec)** | Group A |
| | **DATE BUILT/UPGRADED:** 1970/1983 | **PRESSURE LEVEL:** 7 **(atm. max.)** | |
| Hot Cascade Test Stand | **REPLACEMENT COST:** Part of $40M test center | **INLET TEMP. RANGE:** 3000 **(°F)** | |
| | **OPERATIONAL STATUS:** 1 shift per day 5 days a week | **SPEED RANGE:** N/A **(rpm)** | |
| | | **POWER LEVEL:** N/A **(hp)** | |
| | Blade and vane cascade | | |

TESTING CAPABILITIES: The hot cascade ring provides the capability of evaluating new and modified cooling schemes on vanes and blades in a high-temperature pressurized atmosphere. It allows direct measurement of surface temperature without the engine-related difficulties. The rig uses shop air at 100 psig and a maximum available flow rate of 4.0 lb/sec. Two slave combustors act as direct-fired preheaters and provide test section temperatures up to 3000°F. An electric preheater provides cooling air at a maximum temperature of 1000°F. Surface temperatures are scanned with actuated IR pryometers through three separate viewing ports. An alternative system consists of an AGA thermovision system 680, an IR system providing an isotherm plot.

DATA ACQUISITION: Current method is manual with pressure scanning valves and temperature selectors with digital indicators.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

| Teledyne CAE | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** 16.75 **(in)** | **MAX. FLOW RATE:** 25 **(lb/sec)** | Group A |
| | **DATE BUILT/UPGRADED:** 1946/1973 | **PRESSURE LEVEL:** 1.7 **(atm. max.)** | |
| Turbine 1 and Turbine 2 Cold Flow Rig | **REPLACEMENT COST:** Part of a $40M test center | **INLET TEMP. RANGE:** Ambient – 300 **(°F)** | |
| | **OPERATIONAL STATUS:** 1 shift per day 5 days a week | **SPEED RANGE:** 45 000; 23 000; 11 500 **(rpm)** | |
| | | **POWER LEVEL:** 300; 2400; 450 **(hp)** | |
| | Cold flow axial and radial inflow turbine | | |

TESTING CAPABILITIES: These two cold-flow turbine test stands are for developing axial flow and radial inflow turbine performance; optimizing nozzle, runner, and diffuser design; and conducting research on pressure ratio, rotor and nozzle cooling, and stage output and matching. They are referred to as "cold flow" because there are no provisions to simulate combustor discharge temperatures. Power from the turbine is absorbed by a hydra-brake-type dynamometer. Torque can be measured with a 1000 in-lb in-line torque meter.

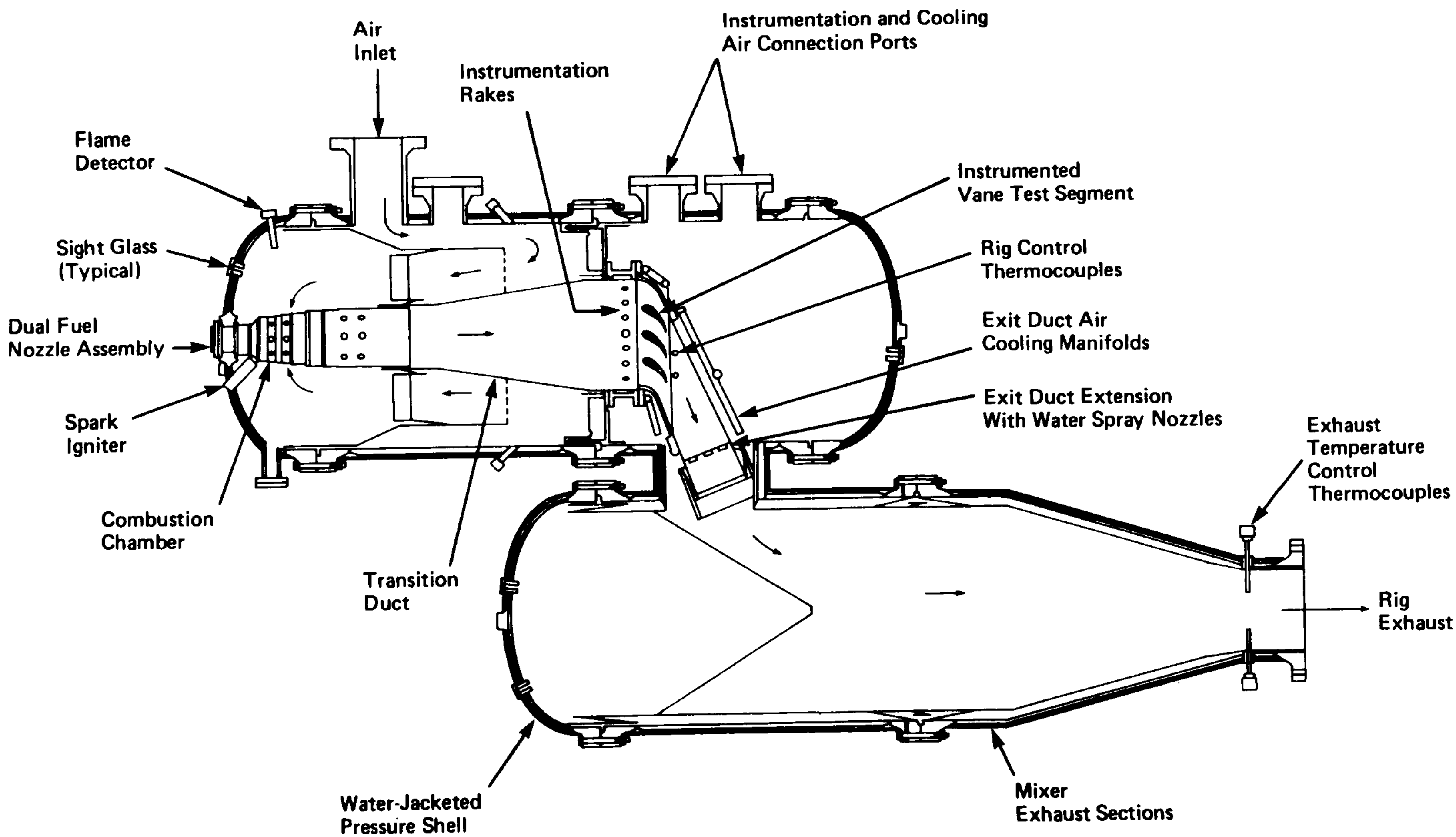
DATA ACQUISITION: 128 channels for pressure, temperature, and any other parameters are available. Additional channels also can be added on. Programming is accomplished with the Perkin-Elmer 7/32 or 3210 computers. Readout is available at the test site from a CRT and decwriter. All or parts of the raw data can be saved on disc or tape for later analysis.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

# VANE COOLING DEVELOPMENT RIG



| Westinghouse Combustion Turbine Systems Division, Concordville, PA | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** (in) 18 x 32 | **MAX. FLOW RATE:** (lb/sec) 90 | Group B |
| | **DATE BUILT/UPGRADED:** 1977/1981 | **PRESSURE LEVEL:** (atm. max.) 20 | |
| Vane Cooling Development Rig | **REPLACEMENT COST:** | **INLET TEMP. RANGE:** (°F) 2200 | |
| | **OPERATIONAL STATUS:** 1 shift per day | **SPEED RANGE:** (rpm) N/A | |
| | | **POWER LEVEL:** (hp) N/A | |
| | Vane cascade flow rig with in-line combustor and cooling air supply | | |

TESTING CAPABILITIES: This facility provides the capability of testing full-scale cooled turbine vanes at full engine operating conditions. A combustion chamber contained in the test rig provides the cascade inlet flow conditions, and can be provided with a range of fuels. Cooling air can be supplied to multiple vane cooling passages with flow, pressure, and temperature controlled independently of main airflow. The test rig can be adapted to various vane cascade geometries.

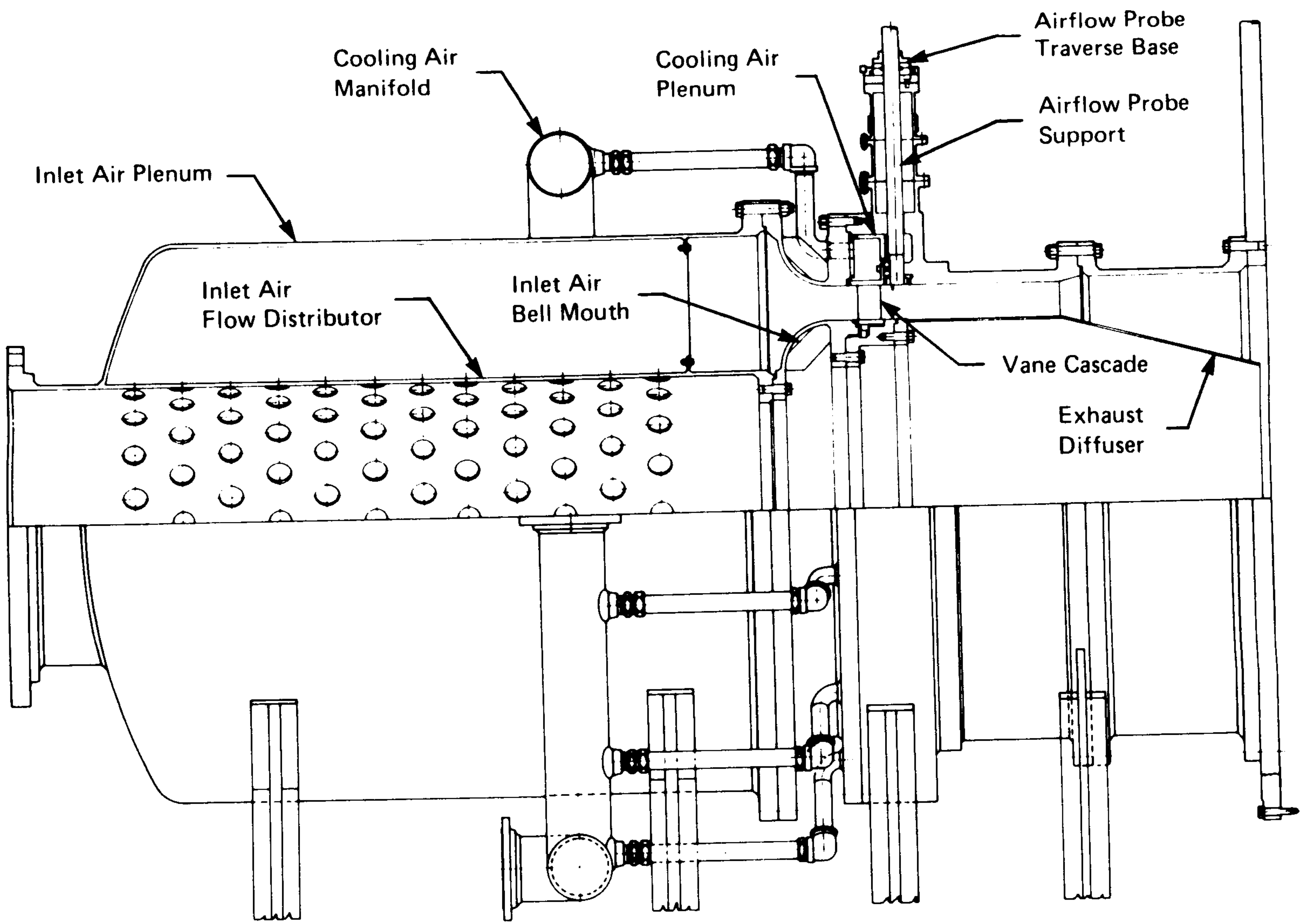
DATA ACQUISITION: Data are acquired, processed, recorded, and displayed by digital/analog system, including Honeywell recorders and Hewlett-Packard 1000F floating-point processor. Nominal system capacity is 800 channels; full data set every 6 seconds.

CURRENT PROGRAMS: Engine vane heat transfer; film and transpiration cooling technology.

PLANNED IMPROVEMENTS: As required for scheduled programs.

LOCAL INFORMATION CONTACT: C. D. Rambert, (215) 358-4769.

# AERODYNAMIC CASCADE TEST RIG
# ROW ONE TURBINE VANE



| Westinghouse Combustion Turbine Systems Division, Concordville, PA | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** (in) 57 dia | **MAX. FLOW RATE:** (lb/sec) 90 | Group B |
| | **DATE BUILT/UPGRADED:** 1983 | **PRESSURE LEVEL:** (atm. max.) 8 | |
| Aerodynamic Cascade Test Rig Row One Turbine Vane | **REPLACEMENT COST:** | **INLET TEMP. RANGE:** (°F) 900 | |
| | **OPERATIONAL STATUS:** New installation | **SPEED RANGE:** (rpm) N/A | |
| | | **POWER LEVEL:** (hp) N/A | |
| | Full annular vane cascade flow rig with cooling air supply and probe traverse system | | |

TESTING CAPABILITIES: This facility provides the capability of aerodynamic testing and full-scale, full annular turbine vane cascade at proper simulation criteria, including Mach number and main air/cooling air temperature ratio. A variety of airflow probes can be traversed downstream of the cascade, with circumferential, radial, axial, and rotational (yaw) modes available.

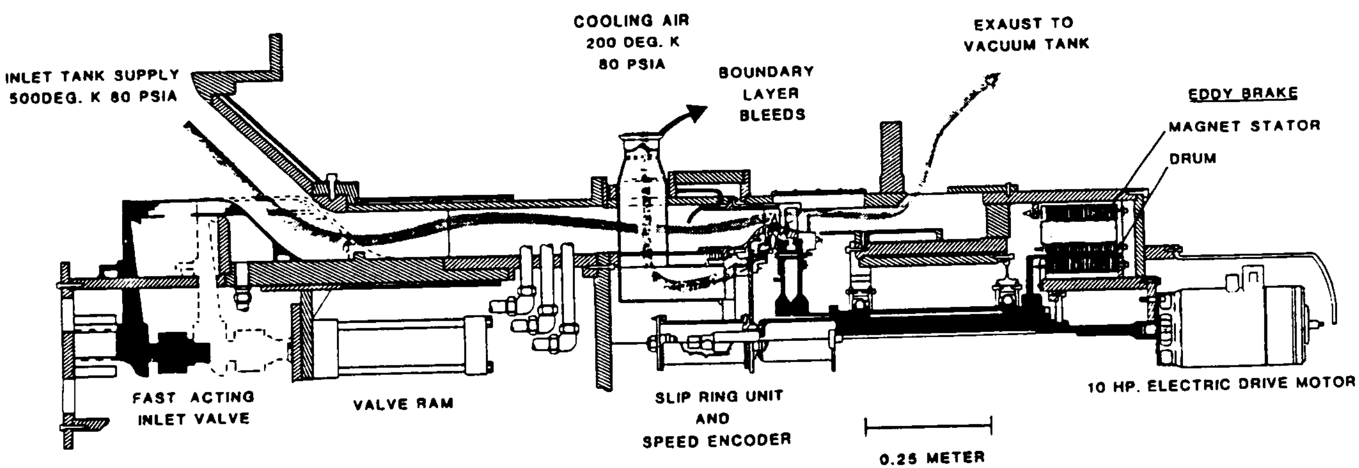
DATA ACQUISITION: Data are acquired, processed, recorded, and displayed by digital/analog system, including Honeywell recorders and Hewlett-Packard 1000F floating-point processor. Nominal system capacity is 800 channels; full data set every 6 seconds. Data system interfaces with multidimensional airflow probe traverse control.

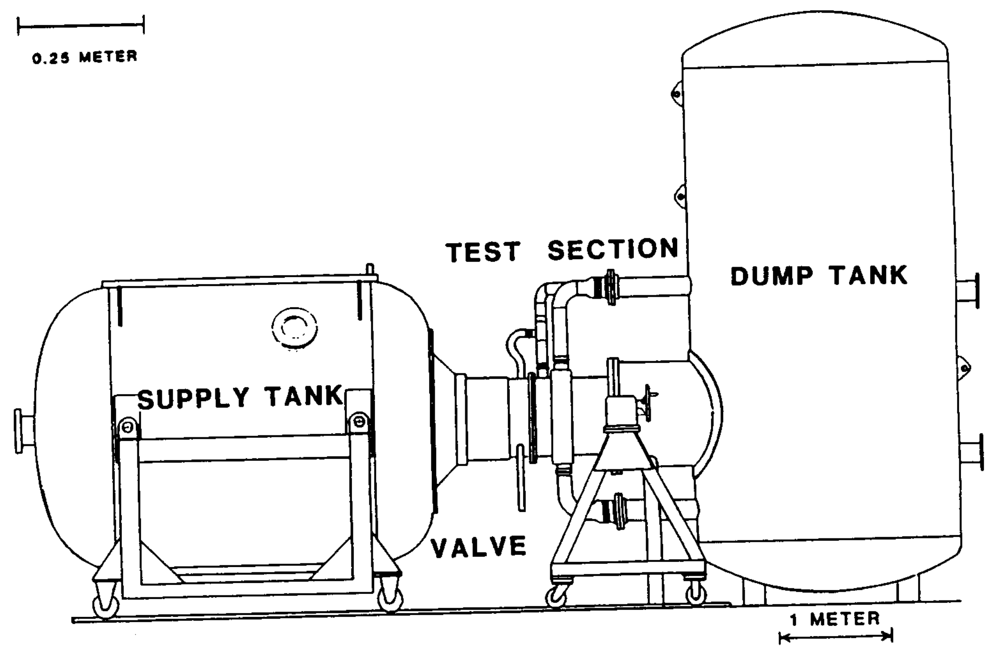
CURRENT PROGRAMS: Determination of flow capacity, aerodynamic losses, exit flow pattern, vane pressure and velocity distributions, and effects of cooling flow.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: C. D. Ramvert, (215) 358-4769.

# BLOWDOWN TURBINE FACILITY



| Massachusetts Institute of Technology | COMPONENT RESEARCH FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 20 dia | **MAX. FLOW RATE: (lb/sec)** 64 (200 scaled) | Group B |
| | **DATE BUILT/UPGRADED:** 1982 | **PRESSURE LEVEL: (atm. max.)** 10 (40 scaled) | |
| Blowdown Turbine Facility | **REPLACEMENT COST:** $2M | **INLET TEMP. RANGE: (°F)** 500 (4000 scaled) | |
| | **OPERATIONAL STATUS:** 2 – 4 runs per day | **SPEED RANGE: (rpm)** 7000 (14 000 scaled) | |
| | | **POWER LEVEL: (hp)** 2000 (52 000 scaled) | |
| | Short duration (0.2 – 0.4 sec) test facility using argon-Freon working fluid to simulate scaled conditions above | | |

TESTING CAPABILITIES: This facility provides the capability of testing cooled high-pressure turbine stages under rigorously scaled but relatively benign conditions for times up to 0.4 sec. The working gas is an argon-Freon mixture chosen to match the ratio of specific heats of a combustor exit flow. All metal to gas temperature ratios are the same as for the full-scale turbine, but the metal temperature has been reduced to room temperature. The Reynolds, Mach, and Prandtl numbers are the same as those for the actual engine timing conditions. The corrected speed and weight flow are constant to better than 1% over 0.2- to 0.4-sec test time.

DATA ACQUISITION: Direct on-line digital data acquisition system, 50 channels at 200 kHz/channel and 48 channels at 12 kHz/channel, 20 million data points per test maximum.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: Fluorescent flow visualization system.

LOCAL INFORMATION CONTACT: A. H. Epstein, Department of Aeronautics and Astronautics, (617) 253-2485.

| Ihi Mizuho Plant, Japan | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 28 dia | **MAX. FLOW RATE: (lb/sec)** 40 | Group A |
| | **DATE BUILT/UPGRADED:** 1981 | **PRESSURE LEVEL: (atm. max.)** 3.5 | |
| High-Pressure Turbine Facility (HPT) | **REPLACEMENT COST:** $2M without air supply system | **INLET TEMP. RANGE: (°F)** 2500 | |
| | **OPERATIONAL STATUS:** 1 shift per day; 2 – 3 runs per month | **SPEED RANGE: (rpm)** 15 000 | |
| | | **POWER LEVEL: (hp)** 6000 | |
| | Inlet pressure can be raised up to 10 atm when alternative air supply is used, reducing the airflow to 22 lb/sec | | |

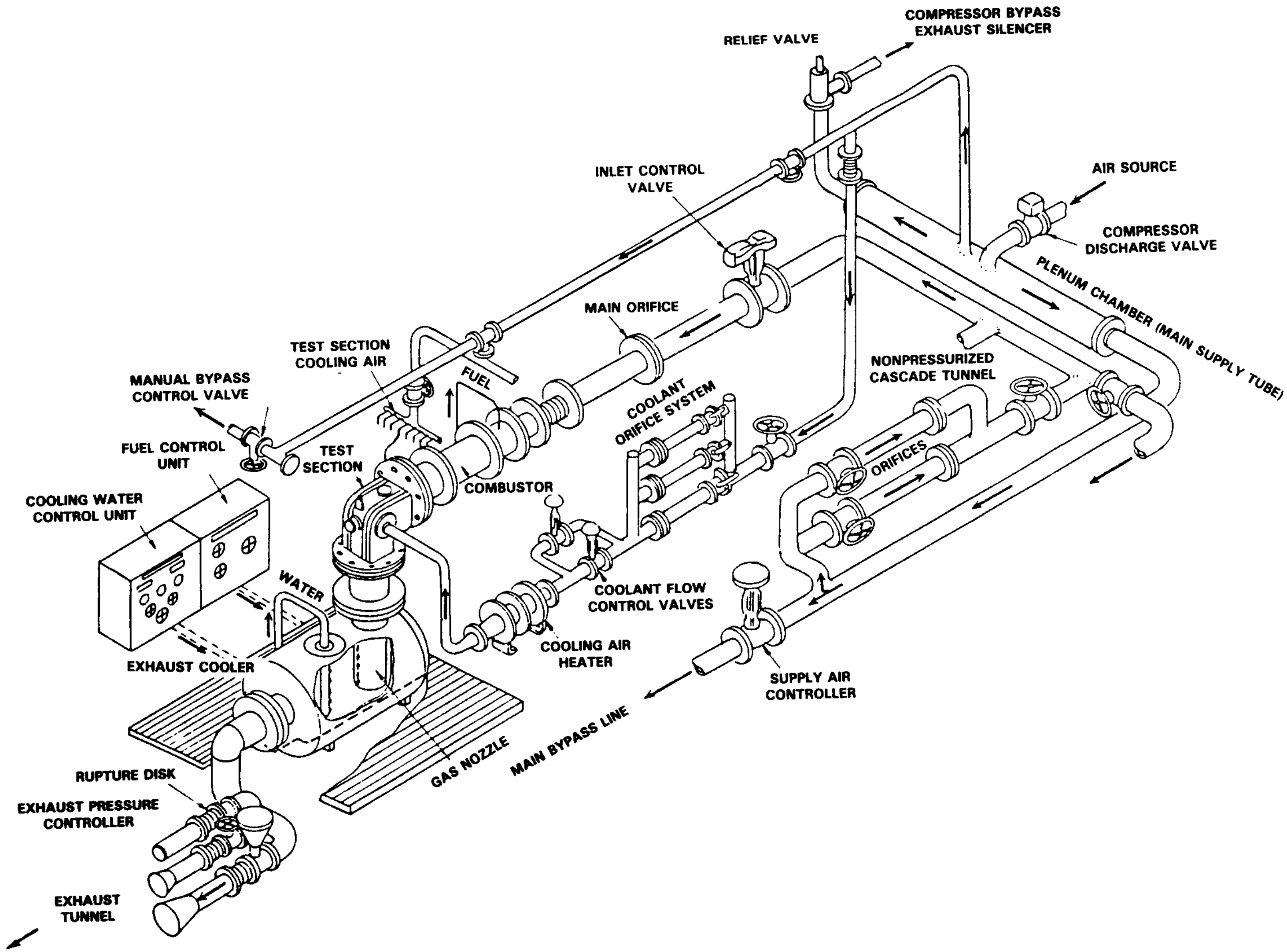
TESTING CAPABILITIES: This facility has the capability of full-scale high-pressure turbine rotating test at a maximum inlet pressure level of 3.5 atm and inlet temperature level of 2500°F. Water dynamometer is used for power absorption and speed control.

DATA ACQUISITION: Above 100 pressure, 100 temperature data can be measured automatically.

CURRENT PROGRAMS: High-loaded, high-efficiency single-stage turbine (with blade cooling systems) rotating test began in January 1985.

PLANNED IMPROVEMENTS: Increase in air supply system has been considered for multistage turbine rig test. Fully automated inlet air temperature control will be installed.

LOCAL INFORMATION CONTACT: K. Murashima, Manager, Research and Development Department, (0425) 56-7241 (Japan).



COMPRESSOR BYPASS EXHAUST SILENCER
RELIEF VALVE
INLET CONTROL VALVE
AIR SOURCE
COMPRESSOR DISCHARGE VALVE
PLENUM CHAMBER (MAIN SUPPLY TUBE)
MAIN ORIFICE
TEST SECTION COOLING AIR
MANUAL BYPASS CONTROL VALVE
FUEL
NONPRESSURIZED CASCADE TUNNEL
COOLANT ORIFICE SYSTEM
TEST SECTION
FUEL CONTROL UNIT
ORIFICES
COMBUSTOR
COOLING WATER CONTROL UNIT
WATER
COOLANT FLOW CONTROL VALVES
COOLING AIR HEATER
EXHAUST COOLER
SUPPLY AIR CONTROLLER
MAIN BYPASS LINE
GAS NOZZLE
RUPTURE DISK
EXHAUST PRESSURE CONTROLLER
EXHAUST TUNNEL

| | TURBINE COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| National Aerospace Laboratory, Japan | **COMPONENT SIZE:** **(in)** 4 x 2.5 | **MAX. FLOW RATE:** **(lb/sec)** 3.7 | Group A |
| | **DATE BUILT/UPGRADED:** 1979 | **PRESSURE LEVEL:** **(atm. max.)** 9 | |
| High-Temperature Turbine Cooling Facility | **REPLACEMENT COST:** $600K | **INLET TEMP. RANGE:** **(°F)** 2200 | |
| | **OPERATIONAL STATUS:** 1 shift per day<br>3 runs per week | **SPEED RANGE:** **(rpm)** N/A<br>**POWER LEVEL:** **(hp)** N/A | |
| | Cooled airfoil cascade | | |

TESTING CAPABILITIES: This facility has the capability of testing cooled turbine airfoils. Coolant can be any kind of air bypassed from unheated mainstream, water from a reservoir, and steam from a boiler. There are electric heaters in a coolant air line for the arrangement of a temperature ratio. Facility operation and data acquisition can be made by one specialist.

DATA ACQUISITION: Fully automated data acquisition, processing, and recording are available by means of the PDP 11/34 minicomputer system.

CURRENT PROGRAMS: Cooling performance tests of full coverage film cooled turbine vane and blades. Heat transfer characteristic test of thermal barrier coating.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Hiroyuki Nouse, Heat Transfer Laboratory, Aeroengine Division, (0422) 47-5911, ext. 473 (Japan).

## COMPRESSOR RESEARCH FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) | Group |
|---|---|---|---|---|---|---|---|
| | U.S. NASA | | | | | | |
| | Lewis Research Center | | | | | | |
| 126 | Large Low-Speed Centrifugal Compressor Facility | 66 | 1500 | Ambient | Atmospheric inlet up to 1.18 press. ratio | Up to 2050 | Unique |
| 127 | Transonic Oscillating Cascade Facility | 950-ft/sec air velocity | 1150 | Ambient | Atmospheric inlet and exhaust | – | Unique |
| 128 | Multistage Axial Flow Compressor Facility | Ambient - 100 | 1500 | Ambient | 0.3 - 5.3 inlet | Up to 18 700 | B |
| 129 | Small Multistage Compressor Facility | 13 | 6000 | Ambient 1200 outlet temp | 1.1 - 1.7 inlet plenum press up to 30:1 press ratio | Up to 60 000 | A |
| 130 | Small Centrifugal Compressor Facility | 13 | 3000 | Ambient | 0.1 - 1.0 inlet | Up to 60 000 | A |
| 131 | Small Single-Stage Centrifugal Compressor Facility | 2 | Turbine Drive | +40 - ambient | 0.1 - 1.3 inlet | Up to 100 000 | A |
| 132 | Single-Stage Axial Flow Compressor | 100 | 3000 | Ambient | 0.3 - 1.0 inlet plenum press | Up to 19 600 | A |
| 133 | Coaxial Jet Facility | Core: 30<br>Fan: 30 | – | Core: 1500<br>Fan: 1500 | 3:1 press. ratio | – | Unique |
| 134 | Fan Acoustic Facility | 80 | 7000 | Ambient | Atmospheric inlet/ exhaust up to 2.5 press. ratio | Up to 20 000 | A |

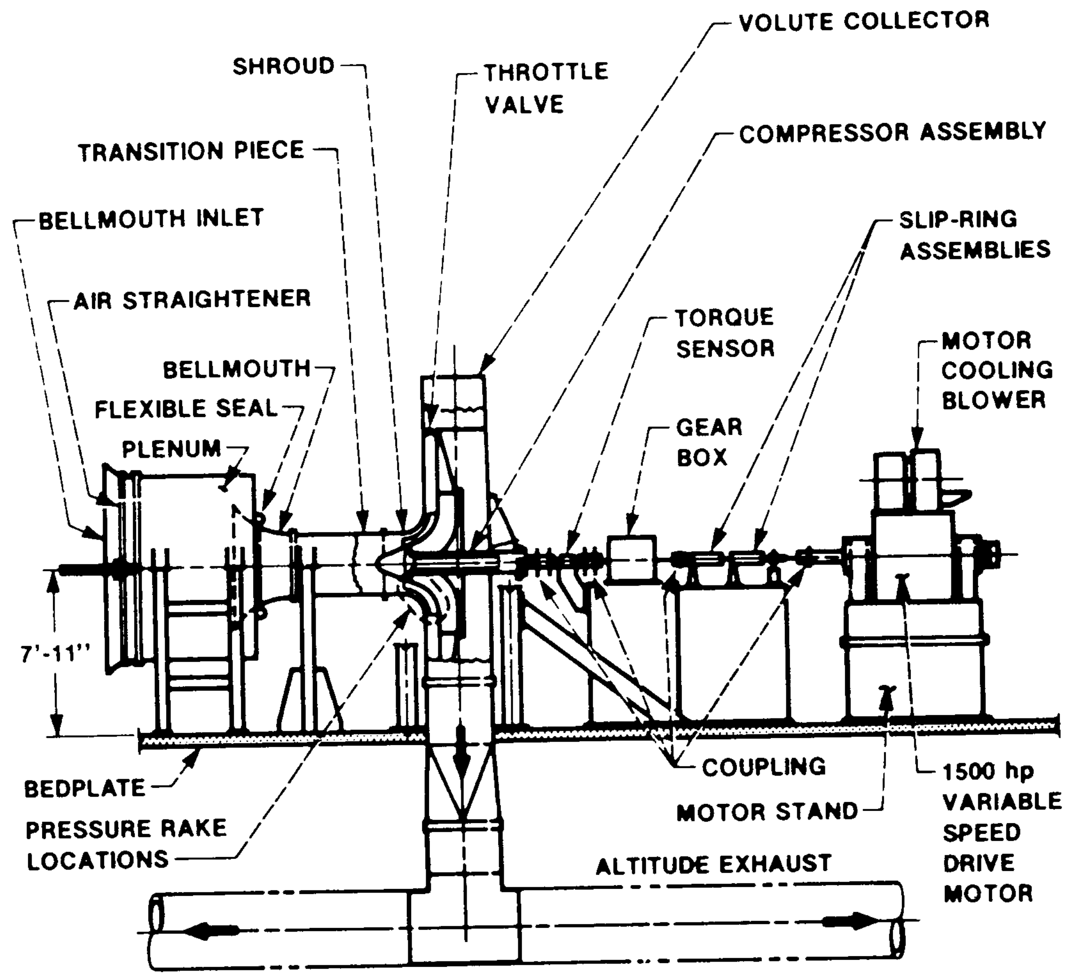
## COMPRESSOR RESEARCH FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) | Group |
|---|---|---|---|---|---|---|---|
| | U.S. DOD | | | | | | |
| | Wright Aeronautical Labs | | | | | | |
| 135 | Compressor Test Facility | 60 | – | Ambient | 1 | 6000 - 21 500 | B |
| 136 | Compressor Research Facility | 500 | 30 000 | Ambient | 1 | 2000 - 3000 | C |
| | U.S. INDUSTRY | | | | | | |
| | Garrett Turbine Engine Company | | | | | | |
| 137 | C-226 Compressor/Fan Test Facility | 30 | 600; 6000 | Atmospheric inlet; 20 exhaust | Atmospheric | 85 000; 21 000 | A |
| 138 | C-114, C-113 Compressor Test Facility | 30 | 600; 6000 | Atmospheric inlet; 20 exhaust | Atmospheric | 85 000; 21 000 | A |
| 139 | Site A Fan Test Facility | 180 | 8000 | Atmospheric | 2 | 11 000 - 21 000 | A |
| | General Electric | | | | | | |
| 139 | Full-Scale Compressor Test/Large Fan Test Facility (FSCT/LFTF) | 1700 fan/400 compressor | 48 000 | -70 - ambient | Atmospheric | 4000 - 15 000 | C |
| | Pratt & Whitney | | | | | | |
| 140 | B33A Stand | – | 6000 | Ambient | Atmospheric | 26 000 | A |
| 141 | X-204 Test Stand | 210; 400 | 21 600 max | -50 - +220 | 22.5"; 40" HgA | 7200 - 15 000 | B |
| 142 | X-211 Test Stand | 550 | 40 000 | Ambient - 250 | Atmospheric | 5000 - 10 989 | C |
| | Telydyne CAE | | | | | | |
| 143 | 3500 hp Compressor Test Stand | 22 | 3500 | -60 - +110 | 1.5 | 39 000 | A |

## COMPRESSOR RESEARCH FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) | Group |
|---|---|---|---|---|---|---|---|
| | <u>U.S. INDUSTRY</u> | | | | | | |
| 144 | 1400-1 and 1400-2 Compressor Test Stands | 22 | 1200; 420 | -65 - +235 | 1.5 | 42 000; 70 000 | A |
| | Westinghouse Combustion Turbine Systems | | | | | | |
| 145 | Combustion Turbine Development Center | | 25 000 | | | 12 000 - 4100 | B |
| | <u>U.S. UNIVERSITY</u> | | | | | | |
| | Massachusetts Institute of Technology | | | | | | |
| 146 | Blowdown Compressor Facility | 100 scaled | – | 212 (max) | 1 | 22 000 | A |
| | <u>JAPAN</u> | | | | | | |
| | National Aerospace Laboratory | | | | | | |
| 147 | Fan/Compressor/Turbine Facility | – | 2160 | Ambient | Ambient | 15 500 | A |
| 148 | Large-Scale Aeroengine Compressor Facility | 310 | 18 000 | Ambient | 2 | 13 000 | B |

# LOW-SPEED CENTRIFUGAL COMPRESSOR



| NASA–Lewis Research Center, Cleveland, OH | COMPRESSOR COMPONENT RESEARCH FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 60 (single stage) | **MAX. FLOW RATE: (lb/sec)** 66 | None |
| | **DATE BUILT/UPGRADED:** 1986 | **PRESSURE LEVEL: (atm. max.)** Atmospheric inlet up to 1.18 pressure ratio | |
| Large Low-Speed Centrifugal Compressor Facility | **REPLACEMENT COST:** $4.2M | **INLET TEMP. RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** Operational in 1986 | **SPEED RANGE: (rpm)** Up to 2050 | |
| | | **POWER LEVEL: (hp)** 1500 | |

TESTING CAPABILITIES: This facility will provide the capability for detail examination in large scale of the internal aerodynamic performance of a centrifugal compressor stage. Extensive aerodynamic instrumentation (i.e., pressure and temperature) plus high-response blade-mounted instrumentation and a laser anemometry system capability will exist. In addition, approximately 300 channels for onboard rotor pressure and temperature data acquisition will be incorporated.

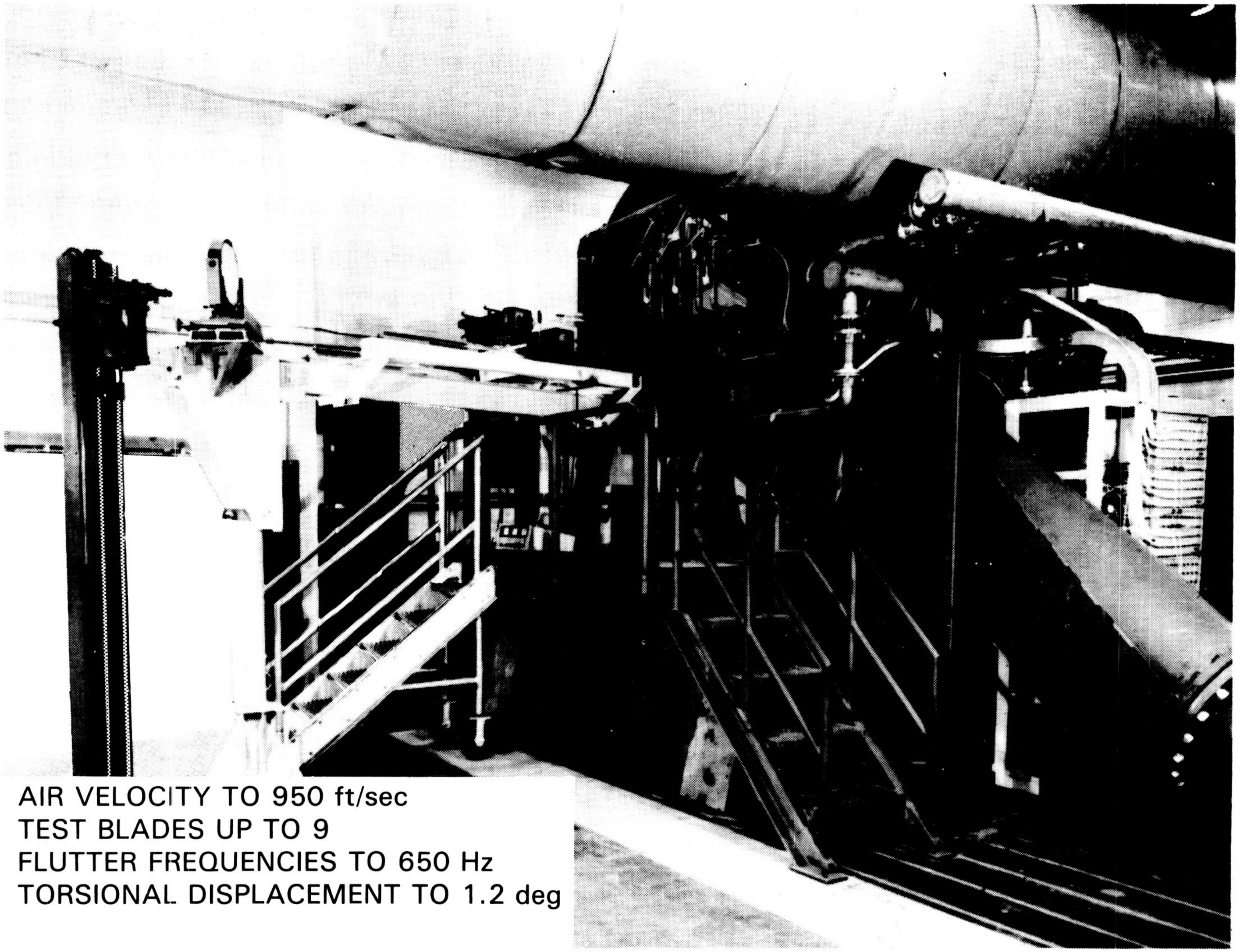
DATA ACQUISITION: Research data are recorded by means of a control data system (ESCORT II) and are processed on the IBM 370 computer for control room display and post-test analysis.

CURRENT PROGRAMS: Initial Programs: Fundamental experiments and code verification.

PLANNED IMPROVEMENTS: Upgrading variable frequency control system (planned C of F 86 Project).

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# TRANSONIC OSCILLATING CASCADE WIND TUNNEL



AIR VELOCITY TO 950 ft/sec
TEST BLADES UP TO 9
FLUTTER FREQUENCIES TO 650 Hz
TORSIONAL DISPLACEMENT TO 1.2 deg

| NASA–Lewis Research Center, Cleveland, OH | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 4 (blade length) | **MAX. FLOW RATE: (lb/sec)** 950 ft/sec air velocity | None |
| | **DATE BUILT/UPGRADED:** 1980 | **PRESSURE LEVEL: (atm. max.)** Atmospheric inlet and exhaust | |
| Transonic Oscillating Cascade Facility | **REPLACEMENT COST:** $1.5M | **INLET TEMP. RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** 1 shift per day | **SPEED RANGE: (rpm)** | |
| | | **POWER LEVEL: (hp)** 100 | |

TESTING CAPABILITIES: This facility provides the capability for testing up to nine airfoils at flow velocities up to 950 feet per second. Flutter frequencies up to 650 Hz with 1.2° torsional displacement can be accommodated. Extensive aerodynamic instrumentation (i.e., pressure and temperature) plus laser anemometry and holographic data acquisition capability exist.

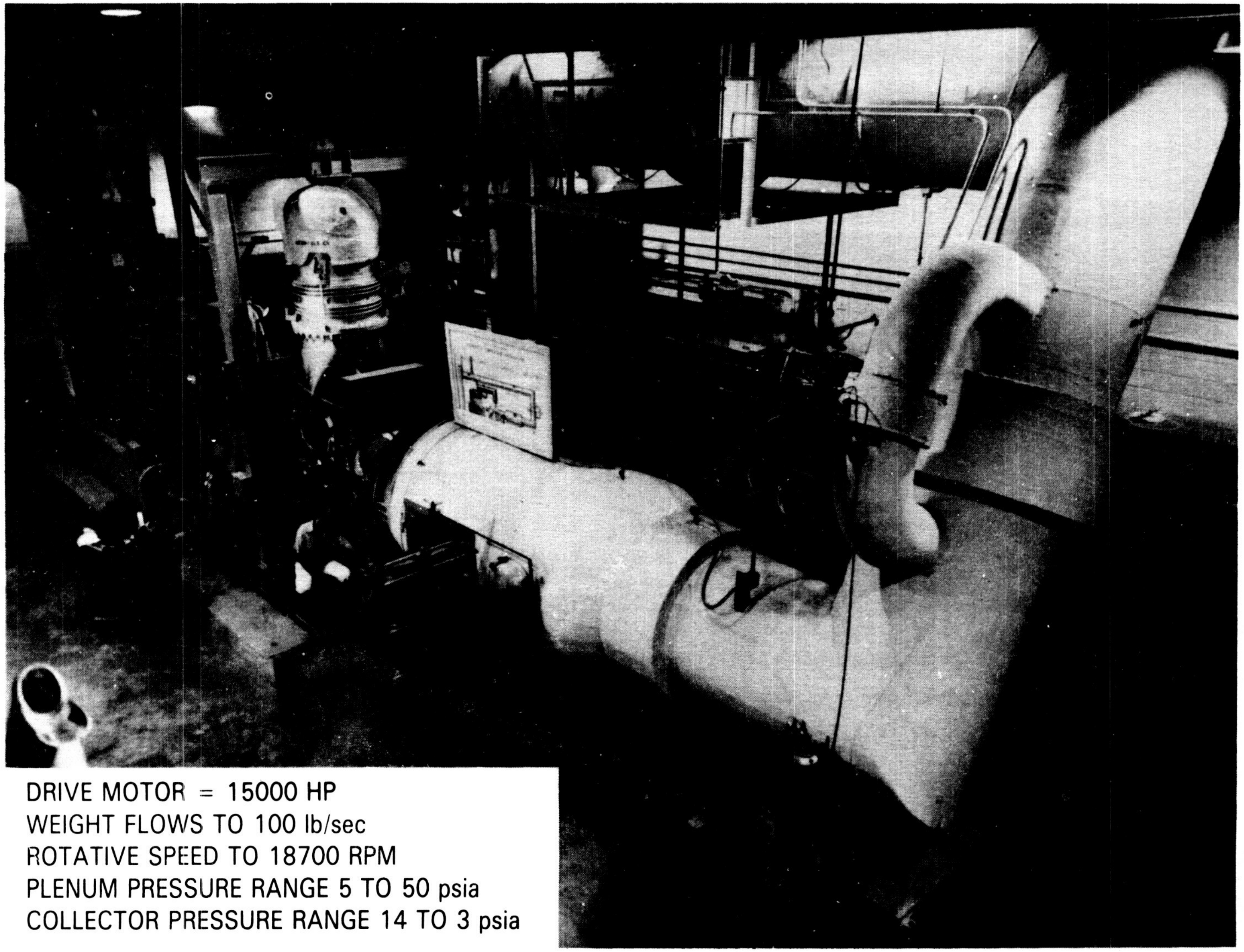
DATA ACQUISITION: Research data are recorded by means of a control data system (ESCORT II) and are processed on the IBM 370 computer for control room display and post-test analysis.

CURRENT PROGRAMS: Subsonic/transonic stall flutter research.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# MULTISTAGE COMPRESSOR FACILITY



DRIVE MOTOR = 15000 HP
WEIGHT FLOWS TO 100 lb/sec
ROTATIVE SPEED TO 18700 RPM
PLENUM PRESSURE RANGE 5 TO 50 psia
COLLECTOR PRESSURE RANGE 14 TO 3 psia

| | COMPRESSOR COMPONENT RESEARCH FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| NASA–Lewis Research Center, Hampton, VA | **COMPONENT SIZE: (in)** 20 dia | **MAX. FLOW RATE: (lb/sec)** Ambient – 100 | Group B |
| | **DATE BUILT/UPGRADED:** 1970 | **PRESSURE LEVEL: (atm. max.)** 0.3 – 3.3 inlet | |
| Multistage Axial Flow Compressor Facility | **REPLACEMENT COST:** $5M | **INLET TEMP. RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** 1 shift per day | **SPEED RANGE: (rpm)** Up to 18 700 | |
| | | **POWER LEVEL: (hp)** 1500 | |

TESTING CAPABILITIES: This facility provides the capability for examining the detailed aerodynamic performance of multistage axial flow compressors. Actual testing conditions simulate environment typical in today's modern aircraft gas turbine engines. Both steady-state and real-time compressor test programs can be accommodated by the use of a fast-acting throttle valve, which controls the compressor airflow while maintaining constant rotational speed. Extensive aerodynamic instrumentation (i.e., pressure and temperature) plus laser anemometry system capability exist.

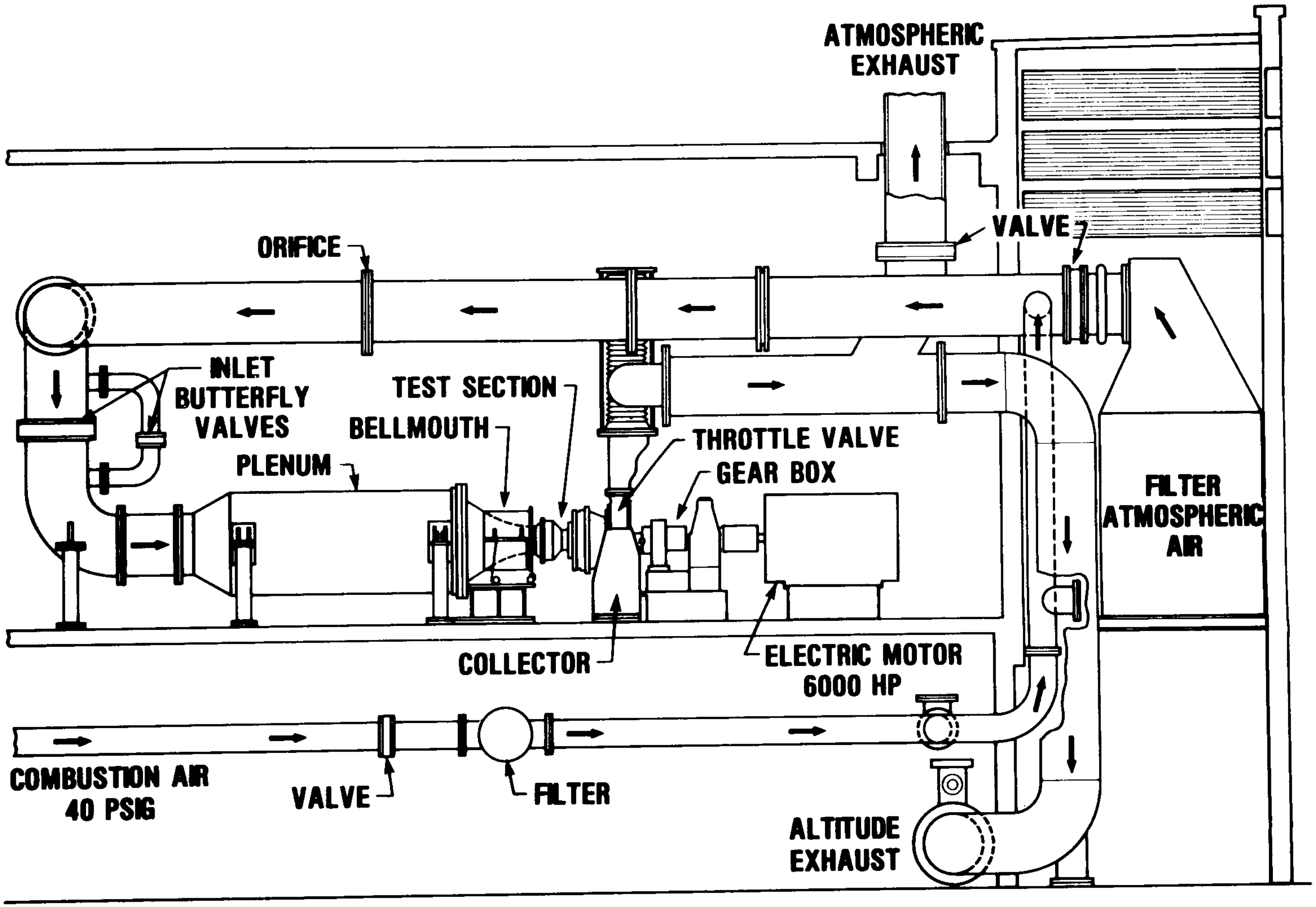
DATA ACQUISITION: Research data are recorded by means of a control data system (ESCORT II) and are processed on the IBM 370 computer for control room display and post-test analysis.

CURRENT PROGRAMS: Flutter/mistuning research and high-speed verification experiments.

PLANNED IMPROVEMENTS: Upgrading variable frequency control system and adding refrigerated air capability (planned C of F 86 projects). Upgrading control system for real-time data acquisition needed for stall recovery research.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# SMALL MULTISTAGE COMPRESSOR FACILITY



| NASA–Lewis Research Center, Cleveland, OH | COMPRESSOR COMPONENT RESEARCH FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 8 inlet rotor dia for axial or centrifugal compressors | **MAX. FLOW RATE: (lb/sec)** 13 | Group A |
| | **DATE BUILT/UPGRADED:** 1988 | **PRESSURE LEVEL: (atm. max.)** 1.1 – 1.7 inlet plenum press<br>Up to 30:1 press ratio | |
| Small Multistage Compressor Facility | **REPLACEMENT COST:** $3.2M | **INLET TEMP. RANGE: (°F)** -70 to Ambient<br>1200 max outlet temp | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE: (rpm)** Up to 60 000 | |
| | | **POWER LEVEL: (hp)** 6000 | |

TESTING CAPABILITIES: This facility will provide the capability for studying the detailed aerodynamic performance of small-size axial and centrifugal compressor stages, either separately or in multistage configurations. Testing conditions simulate conditions typical in today's modern gas turbine aircraft engines. Extensive aerodynamic instrumentation (i.e., pressure and temperature) plus high-response blade-mounted instrumentation and a laser anemometry system capability will exist.

DATA ACQUISITION: Research data are recorded by means of a control data system (ESCORT II) and are processed on the IBM 370 computer for control room display and post-test analysis.

CURRENT PROGRAMS: Facility under construction. Planned for small engine compressor component research.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

| | COMPRESSOR COMPONENT RESEARCH FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| NASA–Lewis Research Center, Cleveland, OH | **COMPONENT SIZE: (in)** 20 dia | **MAX. FLOW RATE: (lb/sec)** 13 | Group A |
| | **DATE BUILT/UPGRADED:** 1983 | **PRESSURE LEVEL: (atm. max.)** 1 – 1.0 inlet plenum press | |
| Small Centrifugal Compressor Facilities | **REPLACEMENT COST:** $2M | **INLET TEMP. RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** 1 shift per day | **SPEED RANGE: (rpm)** Up to 60 000 | |
| | | **POWER LEVEL: (hp)** 3000 | |

TESTING CAPABILITIES: This facility provides the capability for studying the aerodynamic performance of centrifugal compressor stages. Extensive aerodynamic instrumentation (i.e., pressure and temperature) plus high-response blade-mounted instrumentation and a laser anemometry system capability exist.

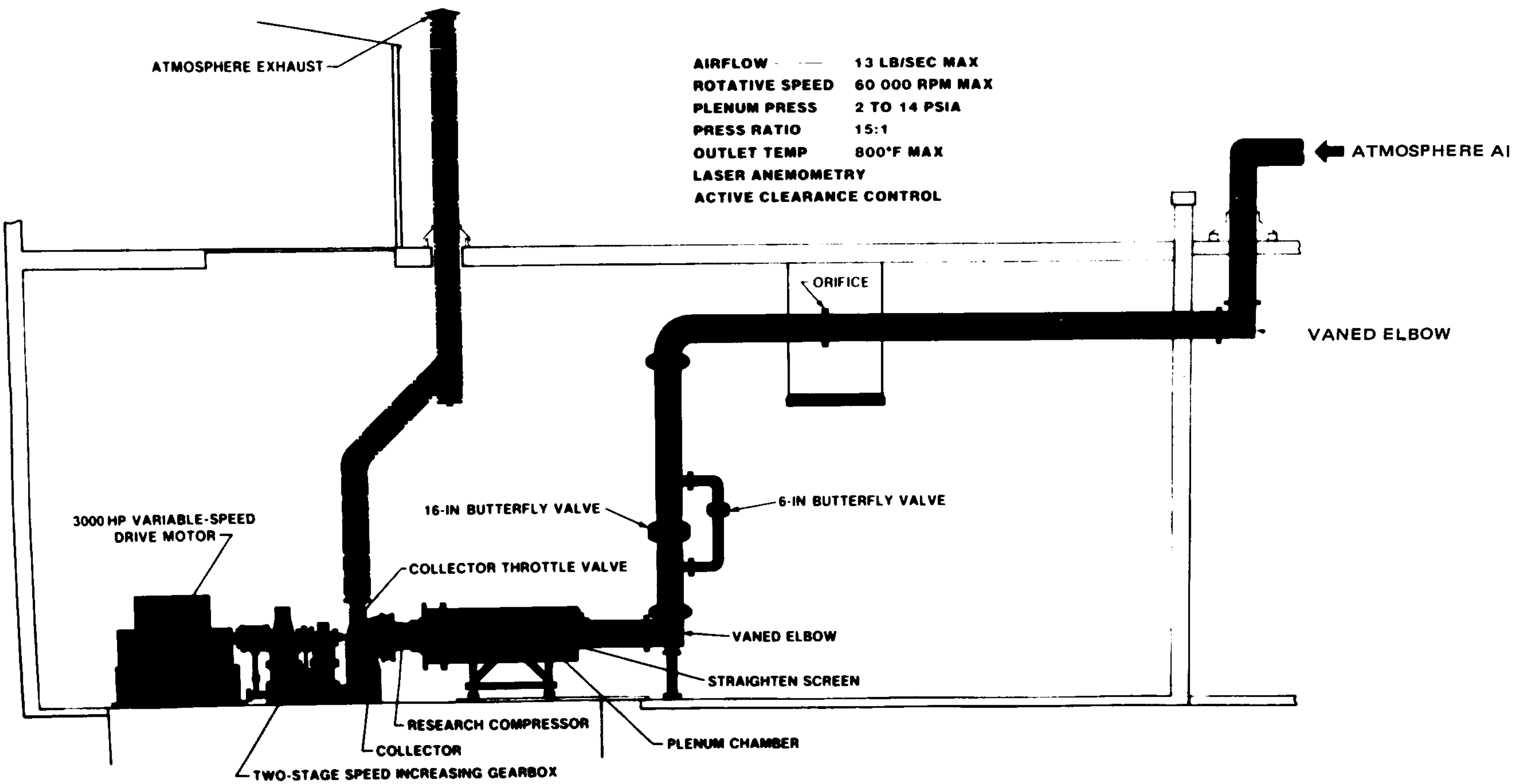
DATA ACQUISITION: Research data are recorded by means of a control data system (ESCORT II) and are processed on the IBM 370 computer for control room display and post-test analysis.

CURRENT PROGRAMS: Component technology (scaling studies) and high-speed verification experiments.

PLANNED IMPROVEMENTS: Upgrading variable frequency control system and adding refrigerated air capability.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# SMALL SINGLE-STAGE CENTIFUGAL COMPRESSOR FACILITY



| NASA–Lewis Research Center, Cleveland, OH | COMPRESSOR COMPONENT RESEARCH FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 6 dia | **MAX. FLOW RATE: (lb/sec)** 2 | Group A |
| | **DATE BUILT/UPGRADED:** 1970 | **PRESSURE LEVEL: (atm. max.)** 0.1 – 1.3 inlet | |
| Small Single-Stage Centrifugal Compressor Facility | **REPLACEMENT COST:** $1M | **INLET TEMP. RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** Inactive | **SPEED RANGE: (rpm)** Up to 100 000 | |
| | | **POWER LEVEL: (hp)** Turbine drive | |
| | Centrifugal Compressor Rotor | | |

TESTING CAPABILITIES: This facility provides the capability for studying the aerodynamic performance of small centrifugal compressor stages. Extensive aerodynamic instrumentation (i.e., pressure and temperature) plus high-response blade-mounted instrumentation capability exist.

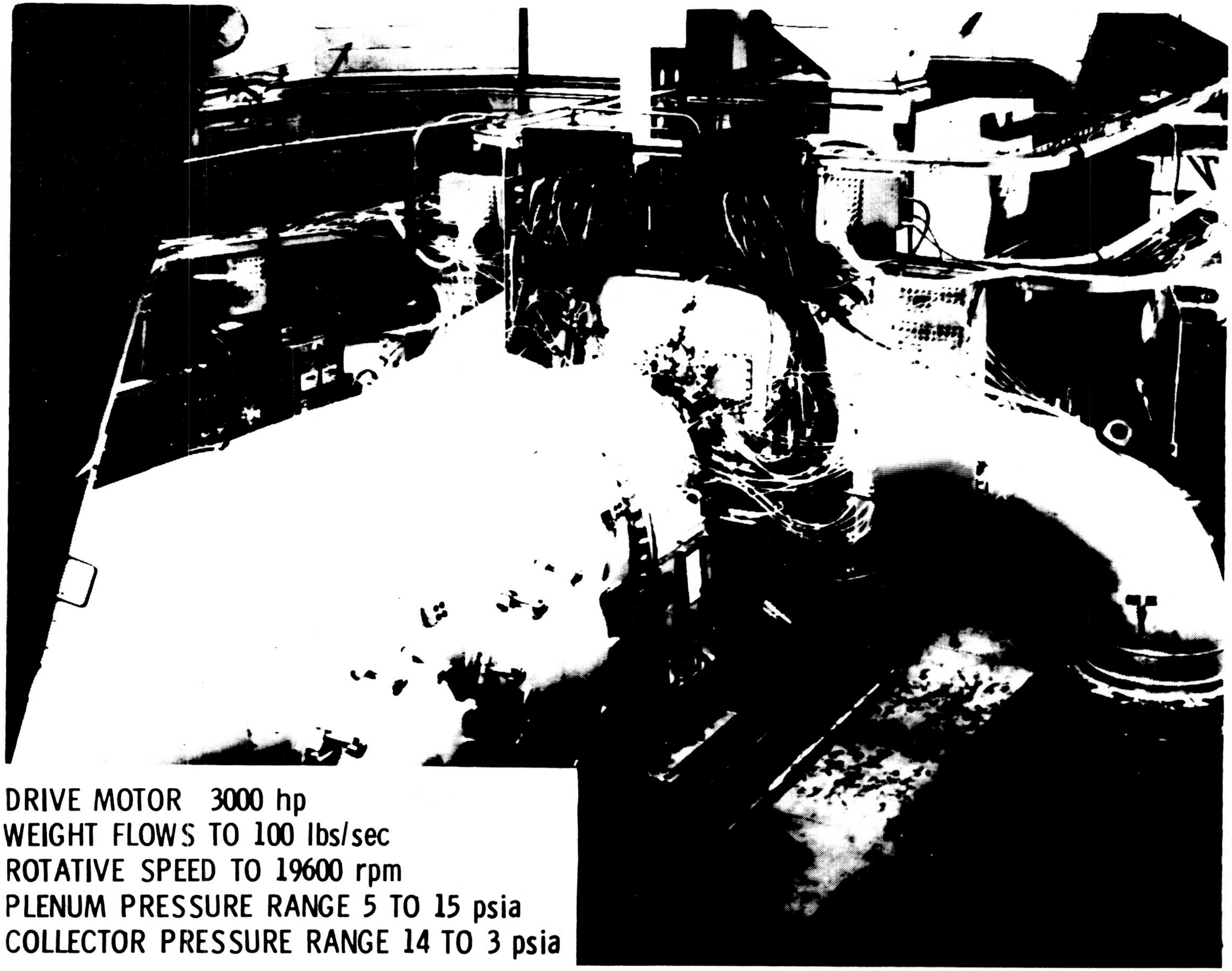
DATA ACQUISITION: Research data are recorded by means of a control data system (ESCORT II) and are processed on the IBM 370 computer for control room display and post-test analysis.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# SINGLE-STAGE AXIAL COMPRESSOR FACILITY



DRIVE MOTOR 3000 hp
WEIGHT FLOWS TO 100 lbs/sec
ROTATIVE SPEED TO 19600 rpm
PLENUM PRESSURE RANGE 5 TO 15 psia
COLLECTOR PRESSURE RANGE 14 TO 3 psia

| | COMPRESSOR COMPONENT RESEARCH FACILITIES | | COMPARABLE FACILITIES |
|---|---|---|---|
| NASA–Lewis Research Center, Cleveland, OH | **COMPONENT SIZE: (in)** 20 dia | **MAX. FLOW RATE: (lb/sec)** 100 | Group A |
| | **DATE BUILT/UPGRADED:** 1970 | **PRESSURE LEVEL: (atm. max.)** 0.3 – 1.0 inlet plenum press | |
| Single-Stage Axial Flow Compressor | **REPLACEMENT COST:** $3.5M | **INLET TEMP. RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** 1 shift per day | **SPEED RANGE: (rpm)** Up to 19 600 | |
| | | **POWER LEVEL: (hp)** 3000 | |

TESTING CAPABILITIES: This facility provides the capability for examining the detailed aerodynamic performance of single-stage axial-flow compressors. Actual testing conditions simulate environment typical in today's modern gas turbine aircraft engines. Extensive aerodynamic instrumentation (i.e., pressure and temperature) plus high-response blade-mounted instrumentation and a laser anemometry system capability exist.

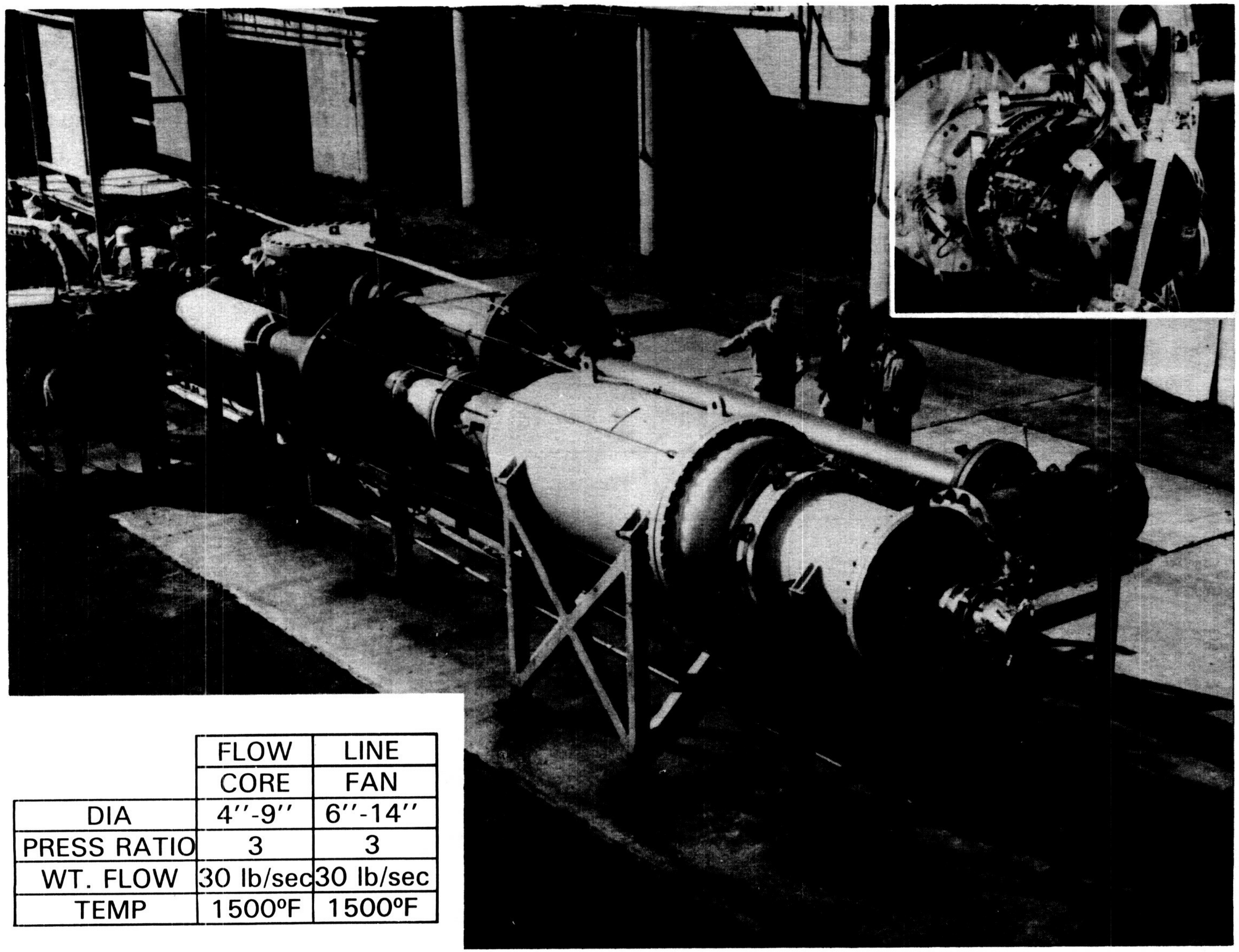
DATA ACQUISITION: Research data are recorded by means of a control data system (ESCORT II) and are processed on the IBM 370 computer for control room display and post-test analysis.

CURRENT PROGRAMS: High-speed verification experiments using laser anemometry.

PLANNED IMPROVEMENTS: Upgrading variable frequency control system and expansion of control room for data acquisition and analysis.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# COAXIAL JET EXCITATION FACILITY



| | FLOW | LINE |
|---|---|---|
| | CORE | FAN |
| DIA | 4″-9″ | 6″-14″ |
| PRESS RATIO | 3 | 3 |
| WT. FLOW | 30 lb/sec | 30 lb/sec |
| TEMP | 1500ºF | 1500ºF |

| NASA–Lewis Research Center, Cleveland, OH | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** Core nozzle: 4 – 9<br>Fan nozzle: 6 – 14 | **MAX. FLOW RATE: (lb/sec)** Core: 30<br>Fan: 30 | Most major engine companies have comparable facilities. |
| | **DATE BUILT/UPGRADED:** 1971/1977 | **PRESSURE LEVEL: (atm. max.)** 3:1 pressure ratio | |
| Coaxial Jet Facility | **REPLACEMENT COST:** $1.3M | **INLET TEMP. RANGE: (°F)** Core: 1500 max<br>Fan: 1500 max | |
| | **OPERATIONAL STATUS:** 1 shift per day | **SPEED RANGE: (rpm)** | |
| | | **POWER LEVEL: (hp)** | |

TESTING CAPABILITIES: This facility provides the capability for studying the internal and external characteristics of coaxial exhaust jet configurations such as forced-mixing co-annular exhaust nozzles. Jet plume pressure and temperature survey, near-field and far-field noise, and hot-wire anemometry data acquisition capability exist.

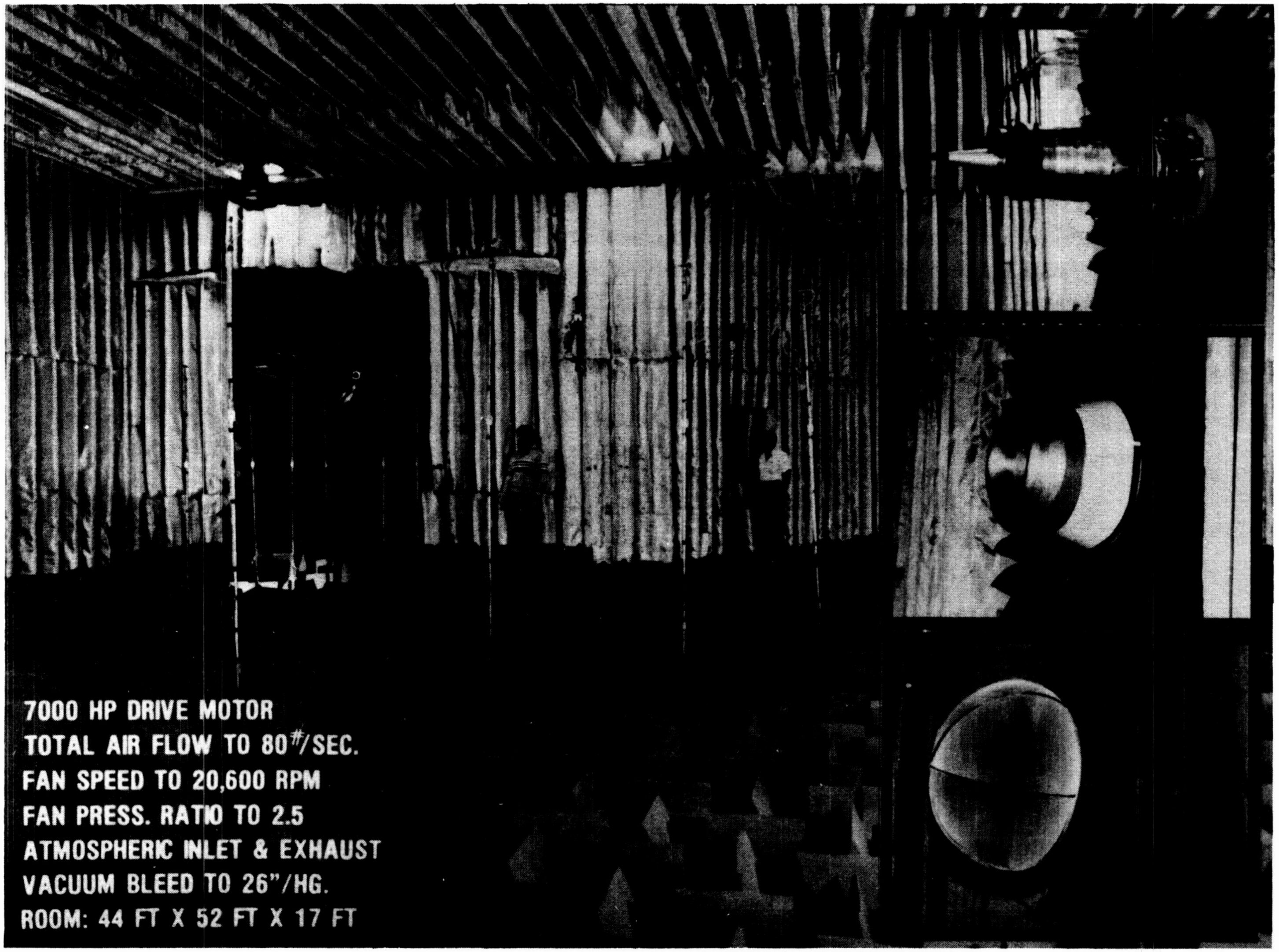
DATA ACQUISITION: Research data are recorded by means of a control data system (ESCORT II) and are processed on the IBM 370 computer for control room display and post-test analysis.

CURRENT PROGRAMS: Unsteady aerodynamics surveys and acoustic excitation of exhaust jets.

PLANNED IMPROVEMENTS: Environmental enclosure planned to improve data acquisition.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# FAN ACOUSTIC FACILITY



| NASA–Lewis Research Center, Cleveland, OH<br><br>Fan Acoustic Facility | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 20 dia single-stage plus inlet or exhaust | **MAX. FLOW RATE: (lb/sec)** 80 | Group A |
| | **DATE BUILT/UPGRADED:** 1975 | **PRESSURE LEVEL: (atm. max.)** Atmospheric inlet/ exhaust up to 2.5 pressure ratio | |
| | **REPLACEMENT COST:** $3.3M | **INLET TEMP. RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** Inactive | **SPEED RANGE: (rpm)** Up to 20 000 | |
| | | **POWER LEVEL: (hp)** 7000 | |
| | Facility incorporates a 44 ft x 52 ft x 17 ft anechoic chamber with a cutoff frequency of 200 Hz. | | |

TESTING CAPABILITIES: This facility provides the capability to examine the acoustic signature, both front and rear quadrants, of single stage fan installations representative of today's modern high bypass ratio turbofan aircraft engine. Extensive acoustic instrumentation exists to measure both the nearfield and farfield noise in an anechoic environment. Limited aerodynamic instrumentation (i.e., pressure and temperature) plus hot wire anemometry capabilities also exist.

DATA ACQUISITION: Research data are recorded by means of a control data system (ESCORT II) and are processed on the IBM 370 computer for control room display and post-test analysis.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

| DOD–AFWAL Aero Propulsion Laboratory | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** | **MAX. FLOW RATE: (lb/sec)** 60 | Group B |
| | **DATE BUILT/UPGRADED:** 1970 | **PRESSURE LEVEL: (atm. max.)** 1 | |
| Compressor Test Facility | **REPLACEMENT COST:** $3M | **INLET TEMP. RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE: (rpm)** 6000 – 21 500 | |
| | | **POWER LEVEL: (hp)** | |
| | Facility operates as closed- or open-loop system.<br>Drive: Electric, speed control through eddy current coupling. | | |

TESTING CAPABILITIES: The facility is currently equipped with an axial compressor test rig capable of handling from 1 to 3 stages of 12 to 18 inches in diameter.

DATA ACQUISITION: 160 channels of pressure at 0–50 psia, 120 channels of chromel-constantan thermocouple, 10 channels of dynamic pressure, and 10 channels of dynamic strain are currently available in addition to facility health-monitoring instrumentation. Data are processed on-line with a MODCOMP computer.

CURRENT PROGRAMS: Studies of interactions between close-coupled transonic blade rows.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Arthur J. Wennerstrom, Technology Branch, (513) 255-7163 or AV 785-7163.

| DOD–AFWAL Aero Propulsion Laboratory | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** 10 dia **(ft)** | **MAX. FLOW RATE:** 500 **(lb/sec)** | Group C |
| | **DATE BUILT/UPGRADED:** 1981 | **PRESSURE LEVEL:** 1 **(atm. max.)** | |
| Compressor Research Facility | **REPLACEMENT COST:** $6M | **INLET TEMP. RANGE:** Ambient **(°F)** | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE:** 2000 – 3000 **(rpm)** | |
| | | **POWER LEVEL:** 30 000 **(hp)** | |

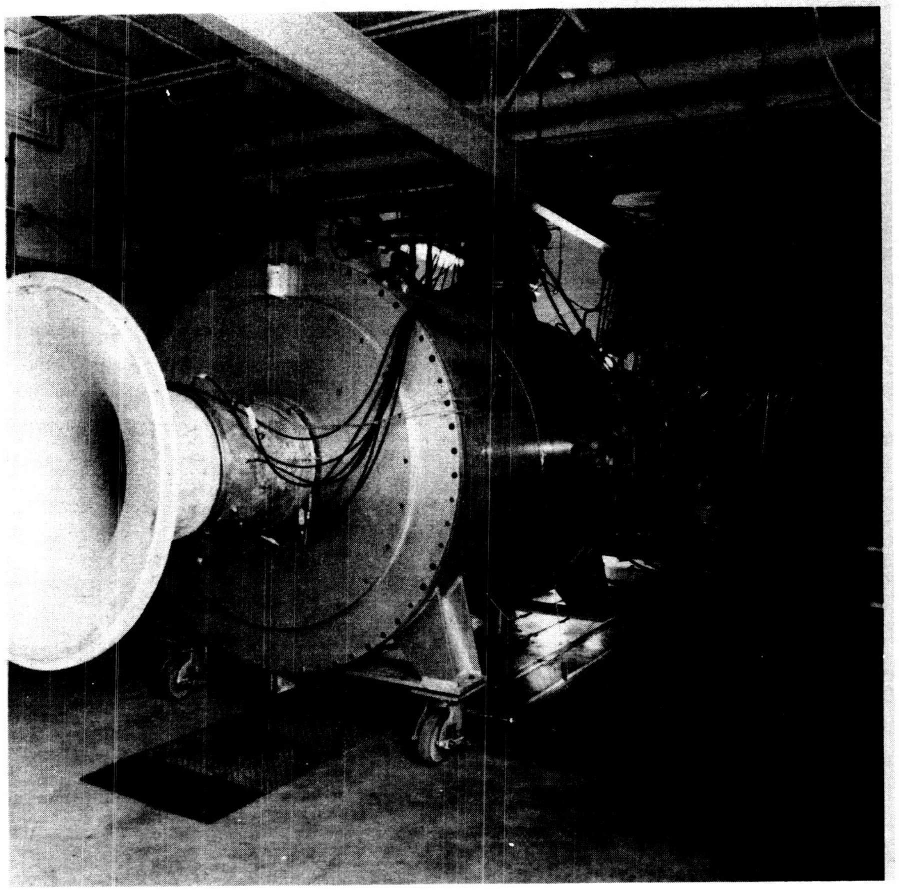
TESTING CAPABILITIES: This facility can handle most core compressors and some fans from operational engines to obtain updated compressor performance maps and to investigate aerodynamic/mechanical interaction. Facility consists of a test tank which runs at ambient temperatures with a rear drive. Synchronous electric motors are used as prime mover, resulting in precise speed control and stability.

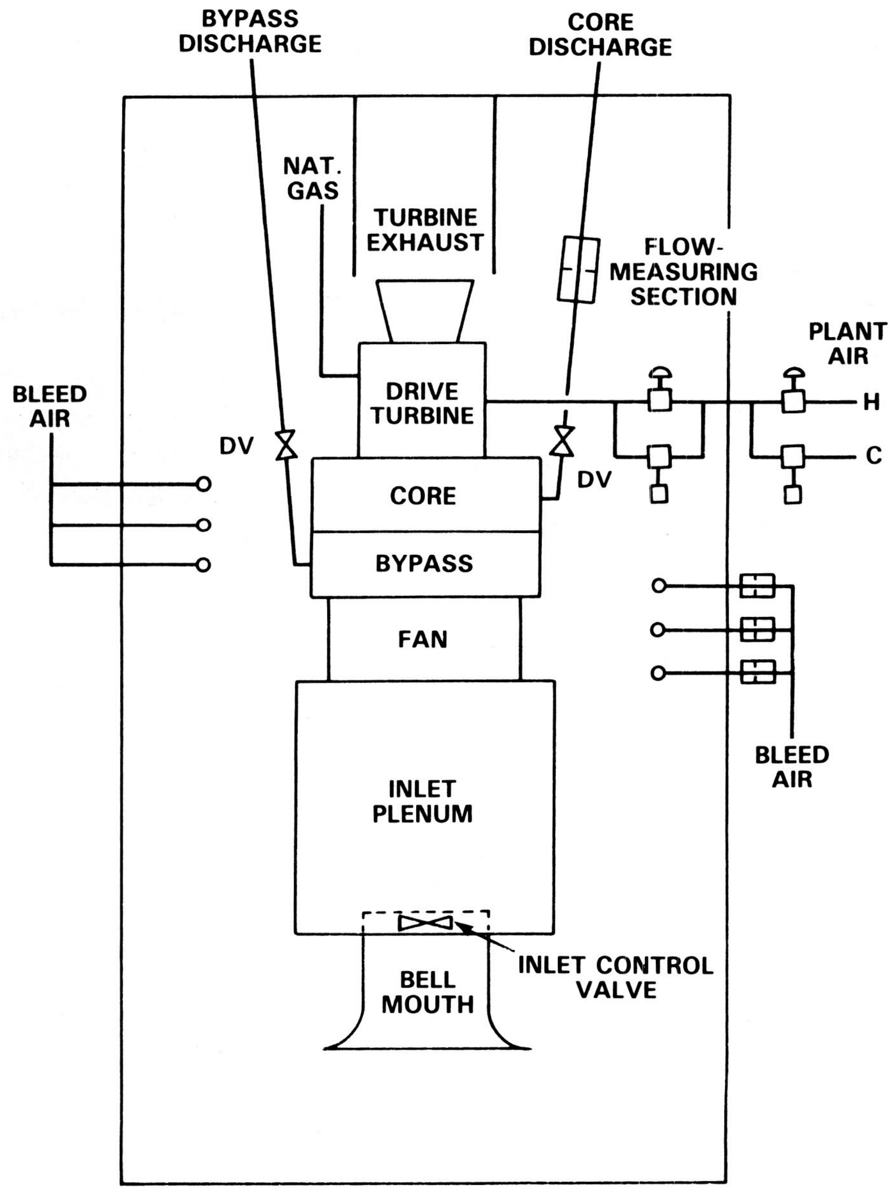
DATA ACQUISITION: This facility is computer-controlled to process up to 1000 channels of digital and analog information on real-time, batch, and post-processing basis. Calculated digital data are displayed, and 150 channels of analog data can be monitored and analyzed during testing.

CURRENT PROGRAMS: Facility checkout is nearing completion. This will be followed by an aerodynamic and aeromechanical mapping of a new research compressor and an aerodynamic mapping (including post-stall) or an operational case compressor.

PLANNED IMPROVEMENTS: No major planned improvements at this time.

LOCAL INFORMATION CONTACT: Dr. Francis R. Ostdiek, Director, Compressor Research Facility, (513) 255-6802 or AV 785-6802.




BYPASS DISCHARGE
CORE DISCHARGE
NAT. GAS
TURBINE EXHAUST
FLOW-MEASURING SECTION
PLANT AIR
H
C
BLEED AIR
DV
DRIVE TURBINE
DV
CORE
BYPASS
FAN
BLEED AIR
INLET PLENUM
BELL MOUTH
INLET CONTROL VALVE

| Garrett Turbine Engine Company, Phoenix, AZ | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** 30 dia **(in)** | **MAX. FLOW RATE:** 30 **(lb/sec)** | Group A |
| | **DATE BUILT/UPGRADED:** 1983 continually upgraded | **PRESSURE LEVEL:** Atmospheric inlet **(atm. max.)** 20 exhaust | |
| C-226 Compressor/Fan Test Facility | **REPLACEMENT COST:** $1M | **INLET TEMP. RANGE:** Atmospheric **(°F)** | |
| | **OPERATIONAL STATUS:** 1 to 2 shifts per day | **SPEED RANGE:** 85 000; 21 000 **(rpm)** | |
| | | **POWER LEVEL:** 600; 6000 **(hp)** | |
| | Compressor or fan aerodynamics | | |

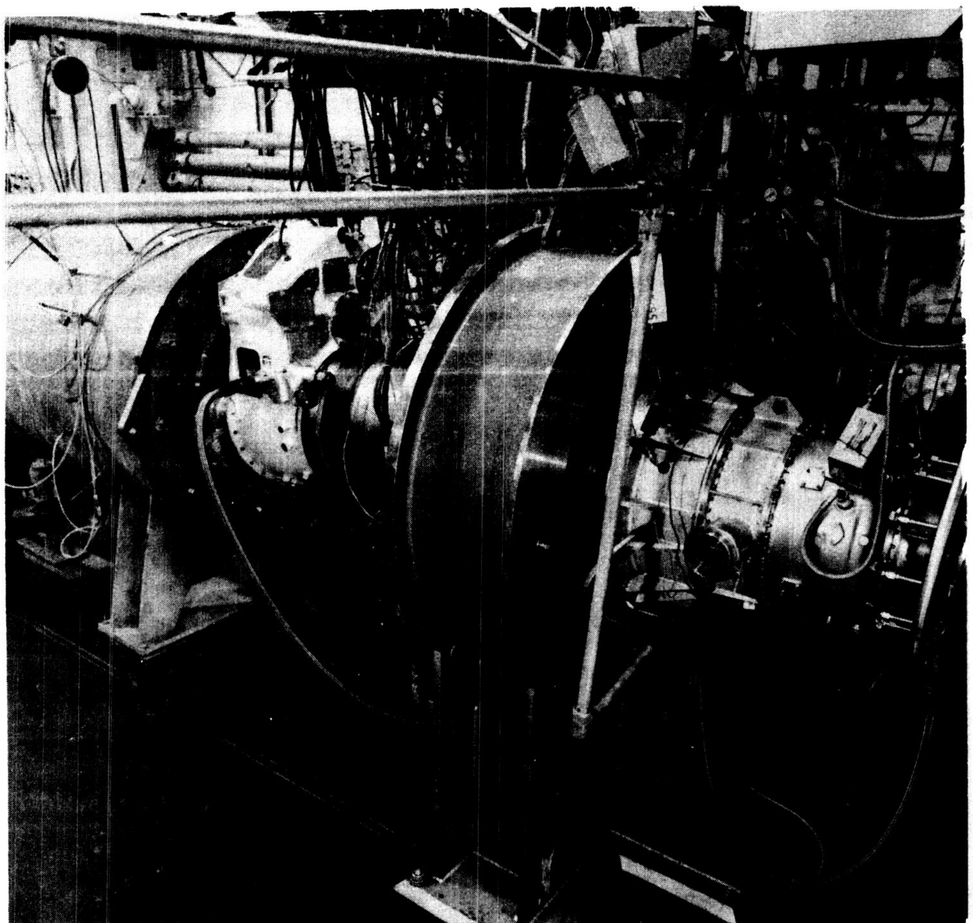
TESTING CAPABILITIES: This facility provides the capability of testing fans and compressors for research development and product improvement. Capabilities include measurement of bleed flows, dynamic and steady-state strain, rotating pressure and temperature, and axial and radial clearances, plus standard aerodynamic measurements. The system is open-loop and powered by gas turbines fueled with natural gas. Discharge plenum provides facilities for controlling and measuring both fan and core engine flows.

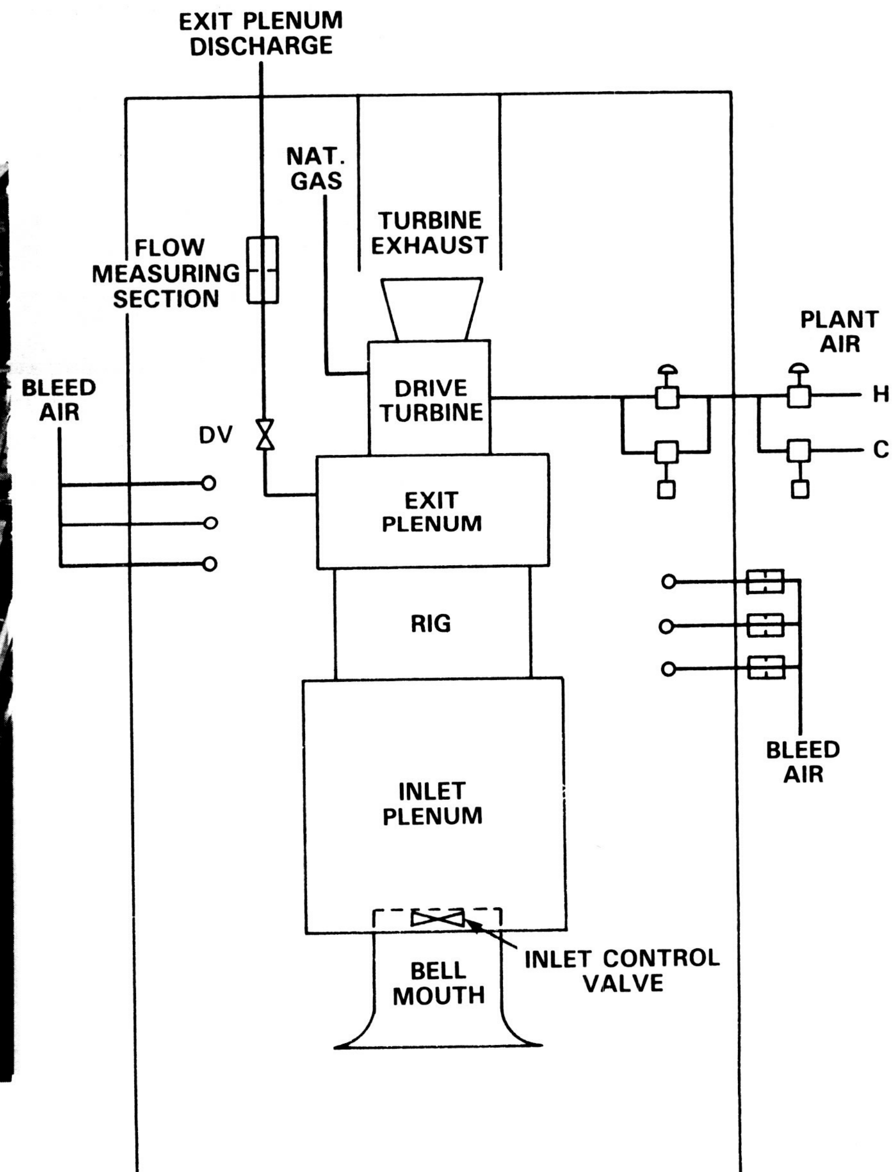
DATA ACQUISITION: Data are recorded by computer via the central data acquisition system. "On-line" performance calculations are provided at the test cell on CRT.

CURRENT PROGRAMS: Full-scale and scaled fan programs.

PLANNED IMPROVEMENTS: Continual update.

LOCAL INFORMATION CONTACT: Robert L. Olive, Engineering Laboratory, (602) 231-4913.




EXIT PLENUM
DISCHARGE
NAT.
GAS
TURBINE
EXHAUST
FLOW
MEASURING
SECTION
PLANT
AIR
BLEED
AIR
DV
DRIVE
TURBINE
H
C
EXIT
PLENUM
RIG
BLEED
AIR
INLET
PLENUM
BELL
MOUTH
INLET CONTROL
VALVE

| Garrett Turbine Engine Company, Phoenix, AZ | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** 30 dia<br>**(in)** | **MAX. FLOW RATE:** 30<br>**(lb/sec)** | Group A |
| | **DATE BUILT/UPGRADED:** 1955<br>continually upgraded | **PRESSURE LEVEL:** Atmospheric inlet<br>**(atm. max.)** 20 exhaust | |
| C-114, C-113 Compressor Test Facility | **REPLACEMENT COST:** $1M | **INLET TEMP. RANGE:** Atmospheric<br>**(°F)** | |
| | **OPERATIONAL STATUS:**<br>1 – 2 shifts per day | **SPEED RANGE:** 85 000; 21 000<br>**(rpm)**<br>**POWER LEVEL:** 600; 6000<br>**(hp)** | |
| | Two compressor test facilities allow parallel activities of setup and testing, and allow choice of drive turbine operating envelopes | | |

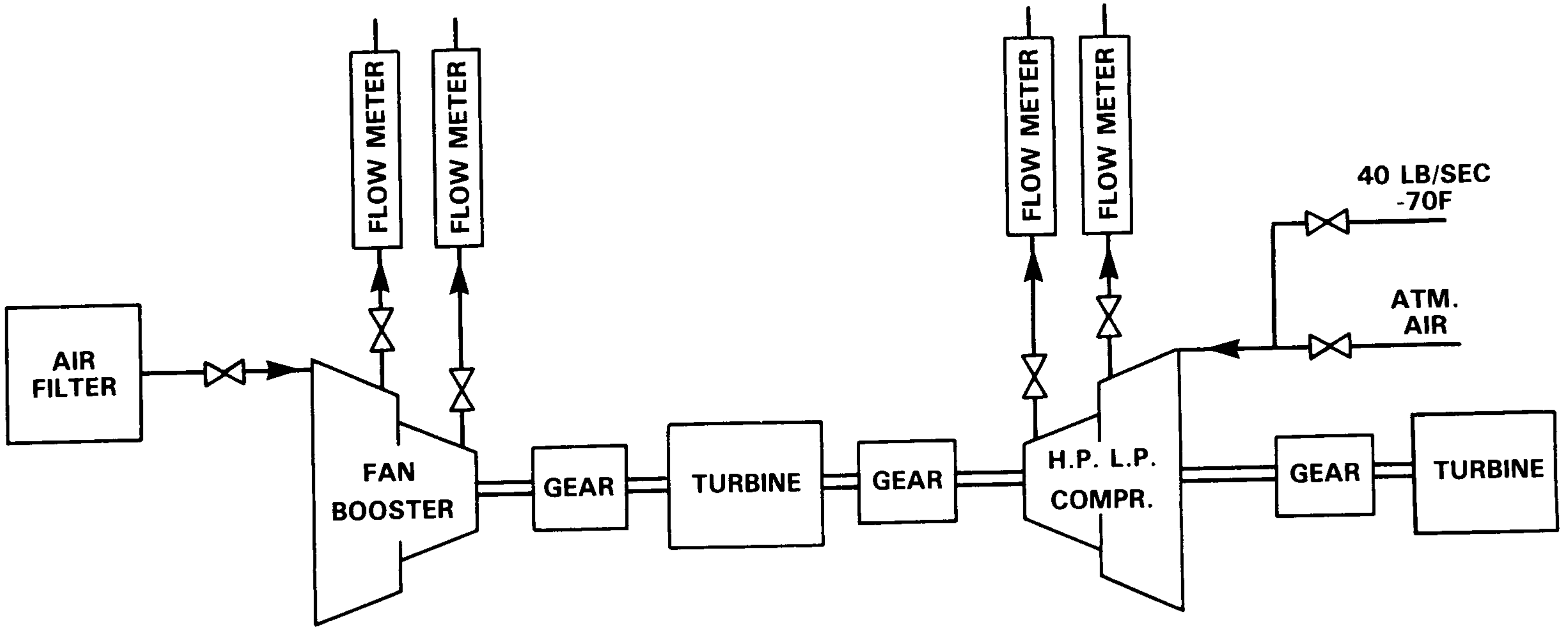
TESTING CAPABILITIES: This facility provides the capability of testing axial and centrifugal compressors for research, development, and product improvement. Capabilities include measurement of bleed flows, dynamic and steady-state strain, rotating pressure and temperature, and axial and radial clearances, plus standard aerodynamic measurements. The system is open-loop and is powered by gas turbines fueled with natural gas.

DATA ACQUISITION: Data are recorded by computer via the central data acquisition system. "On-line" performance calculations are provided at the test cell on CRT.

CURRENT PROGRAMS: Full-scale development and research compressor programs.

PLANNED IMPROVEMENTS: Continual update.

LOCAL INFORMATION CONTACT: Robert L. Olive, Engineering Laboratory, (602) 231-4913.




LARGE FAN TEST
FACILITY (LFTF)
SCHEMATIC

FULL-SCALE COMPRESSOR
TEST FACILITY (FSCT)
SCHEMATIC

| General Electric Company, Lynn, MA | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** FSCT: 10 dia inlet<br>LFTF: 15 dia inlet | **MAX. FLOW RATE: (lb/sec)** 1700 fan/<br>400 compressor | Group C |
| | **DATE BUILT/UPGRADED:** 1949/1964 | **PRESSURE LEVEL: (atm. max.)** Atmospheric | |
| Full Scale Compressor Test/ Large Fan Test Facility<br><br>FSCT/LFTF | **REPLACEMENT COST:** $25M | **INLET TEMP. RANGE: (°F)** -70 to ambient | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE: (rpm)** 4000 – 15 000 | |
| | | **POWER LEVEL: (hp)** 48 000 | |

TESTING CAPABILITIES: The original FSCT was designed to test a compressor rated at 300-lb/sec corrected flow and design pressure ratio of 10, at a wide range of inlet pressure and temperature, using a 33 000 hp variable speed steam turbine drive. A compressor bypass low exhaust system was added in 1954. Ten years later, the large fan test facility was installed at the other end of the steam turbine drive, an additional 15 000 hp steam turbine was installed at the inlet end of the FSCT, enabling the LFTF to operate at 48 000 hp, and dual rotor compressor testing in the FSCT. All compressor tests are now open cycle, so that very high discharge air temperature can be cooled by water evaporation.

DATA ACQUISITION:

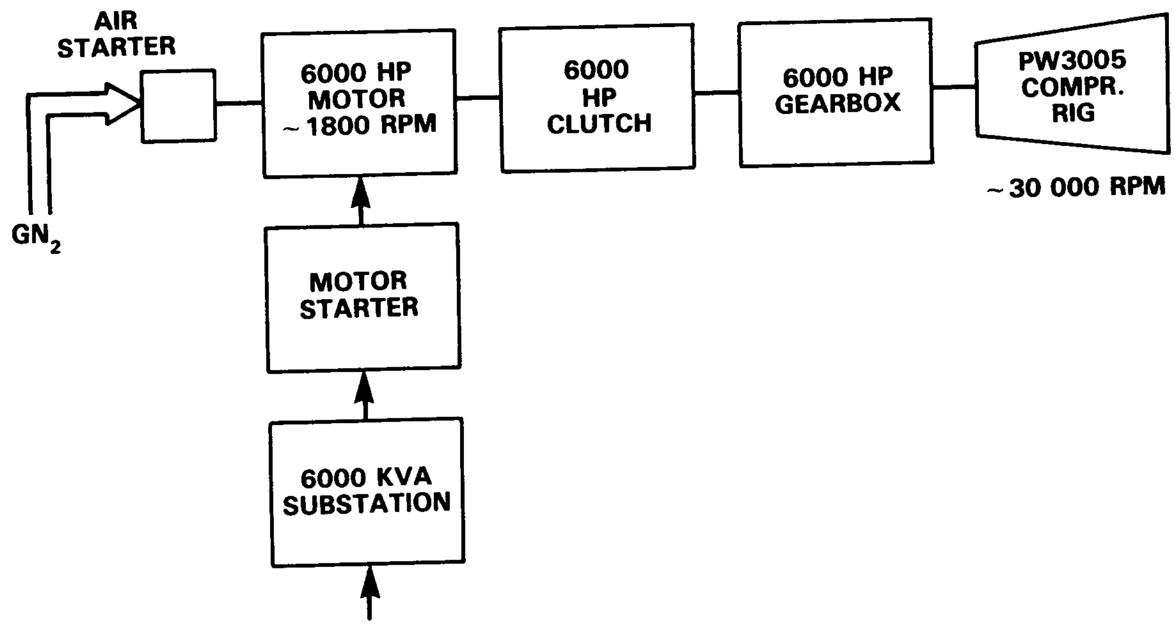
| Facility | Press | Temp | Dynamic/Stress | Miscellaneous | Total Channels |
|---|---|---|---|---|---|
| FSCT | 960 | 350 | 250 | 70 | 1630 |
| LFTF | 480 | 350 | 250 | 70 | 1150 |

CURRENT PROGRAMS: Testing advanced engine fans and compressors.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: K. A. Moser, 1-29 K3, General Electric Company, 1000 Western Avenue, Lynn, MA 01910, (617) 594-4664.

# B33A DRIVE SYSTEM FOR PW-3005 COMPRESSOR



| Pratt & Whitney Aircraft, Government Products Division | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** 48 dia max. **(in)** | **MAX. FLOW RATE:** **(lb/sec)** | Group A |
| | **DATE BUILT/UPGRADED:** 1982/1984 | **PRESSURE LEVEL:** Atmospheric **(atm. max.)** | |
| Compressor Test Facility<br><br>B33A Stand | **REPLACEMENT COST:** | **INLET TEMP. RANGE:** Ambient **(°F)** | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE:** 26 000 **(rpm)** | |
| | | **POWER LEVEL:** 6000 **(hp)** | |

TESTING CAPABILITIES: This facility provides the capability of testing compressors at up to 26 000 rpm and 6000 hp. Both altitude and sea level inlet pressures can be provided. The drive consists of a 6000 hp electric motor driving a speed-increasing gearbox through a variable speed magnetic clutch. Facility features include a variable restriction inlet duct, computer-controlled compressor discharge valves, a programmable compressor vane angle control system, and various lubrication and cooling systems.

DATA ACQUISITION: Data acquisition is provided by a Neff Model 620 system controlled by a DEC PDP 11/60 computer. The system is used for on-line data acquisition, health monitor display, and display of rig performance calculations. Graphics plots of transient data are available within a few minutes of data acquisition. The system has the following measurement capabilities:

- 282 Scanivalve pressures
- 176 individual pressures
- 36 Kulite high-response pressures
- 145 temperatures
- 8 speed and flow channels
- 28 miscellaneous

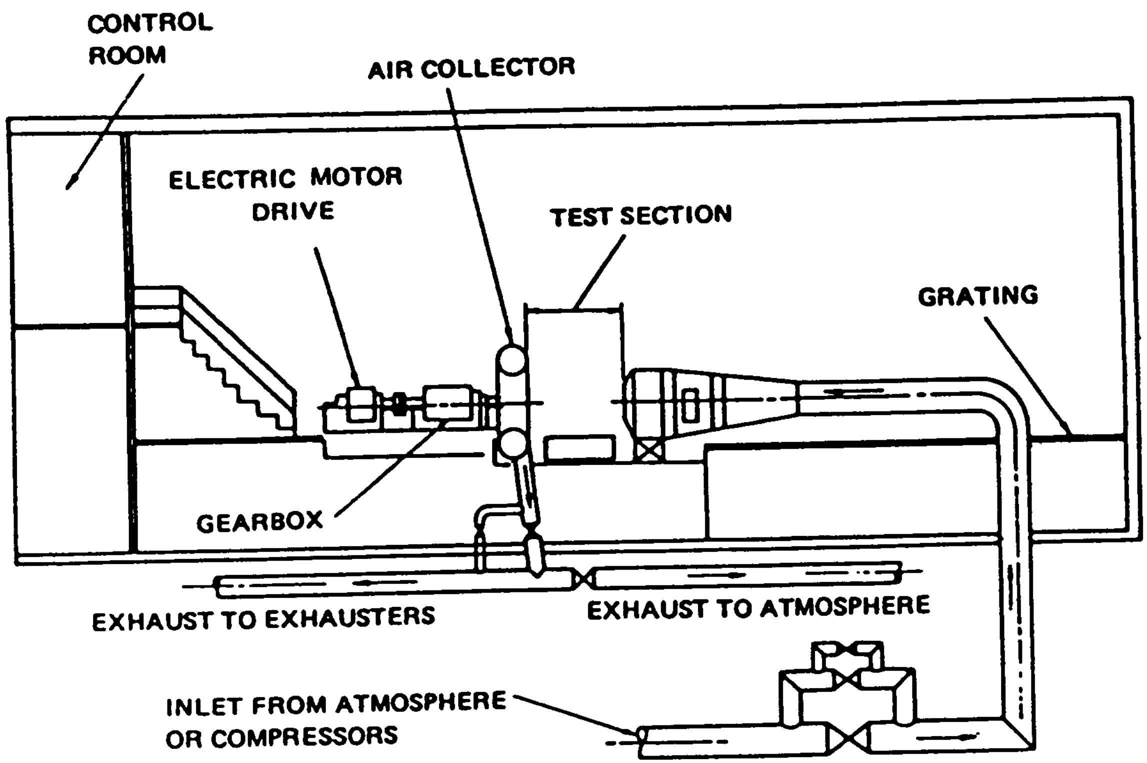
In addition to digital recording, there is a separate 72-channel analog recording and monitoring system for use with strain gage, dynamic pressures, vibrations, and other measurements.

CURRENT PROGRAMS: Compressor development.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Donald C. Craig, Superintendent of Test Operations, Mail Stop 724-02, (305) 840-1135.

# X-204 TEST STAND
# WILLGOOS LABORATORY



| | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| United Technologies<br><br>Pratt & Whitney Aircraft | **COMPONENT SIZE: (in)** Bedplate 22'L x 9'W<br>Centerline 7' – 5" | **MAX. FLOW RATE: (lb/sec)** 210/400 | |
| | **DATE BUILT/UPGRADED:** 1950 | **PRESSURE LEVEL: (atm. max.)** 22.5"/40" HgA | |
| X-204<br>Test Stand | **REPLACEMENT COST:** $12M | **INLET TEMP. RANGE: (°F)** -50 – +220 | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE: (rpm)** 7200 – 15 000 | |
| | | **POWER LEVEL: (hp)** 21 600 max | |
| | Full-scale fan/compressor development | | Group B |

TESTING CAPABILITIES: The X-204 stand is an electric-motor-driven component stand designed for development testing of full-scale gas turbine compressors or any other miscellaneous component requiring a large external source of rotational power. Components can be tested at simulated altitude or sea level conditions.

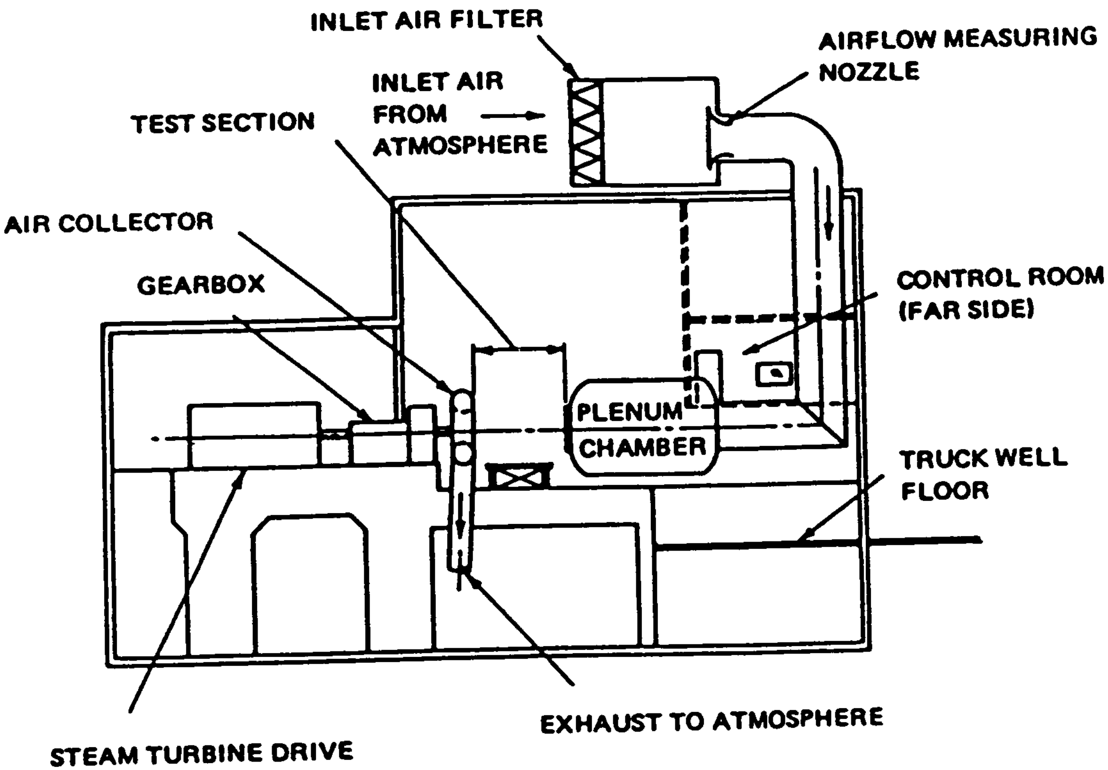
DATA ACQUISITION: Test data are automatically transmitted to the Sigma 8 computer located in the Engineering Building. Computed data are returned within 3 minutes and displayed on an alphanumeric scope. A total of 1000 channels is available, 575 pressures, 359 temperatures, and 66 miscellaneous. Wiring also is provided to an outside terminal for up to 4 strain gage vanes (tape recording).

CURRENT PROGRAMS: Full-scale fan/compressor component research and development.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Joseph A. Barlock, Manager, Experimental Test Equipment Engineering, East Hartford, CT, (203) 565-2091.

# X-211 TEST STAND
# WILLGOOS LABORATORY



| | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| United Technologies<br><br>Pratt & Whitney Aircraft | **COMPONENT SIZE: (in)** Bedplate 8' – 10 W x 33' – 6"L, Centerline 7' – 0" | **MAX. FLOW RATE: (lb/sec)** 550 | Group C |
| | **DATE BUILT/UPGRADED:** 1957 | **PRESSURE LEVEL: (atm. max.)** Atmospheric | |
| X-211 Test Stand | **REPLACEMENT COST:** $12M | **INLET TEMP. RANGE: (°F)** Ambient – 250 | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE: (rpm)** 500 – 10 989 | |
| | | **POWER LEVEL: (hp)** 40 000 | |
| | Steam turbine rated at 40 000 hp at 2335 to 3600 rpm | | |

TESTING CAPABILITIES: The X-211 stand is a turbine-driven component stand designed to develop full-scale gas turbine compressors or any miscellaneous component requiring a large external source of rotational power.

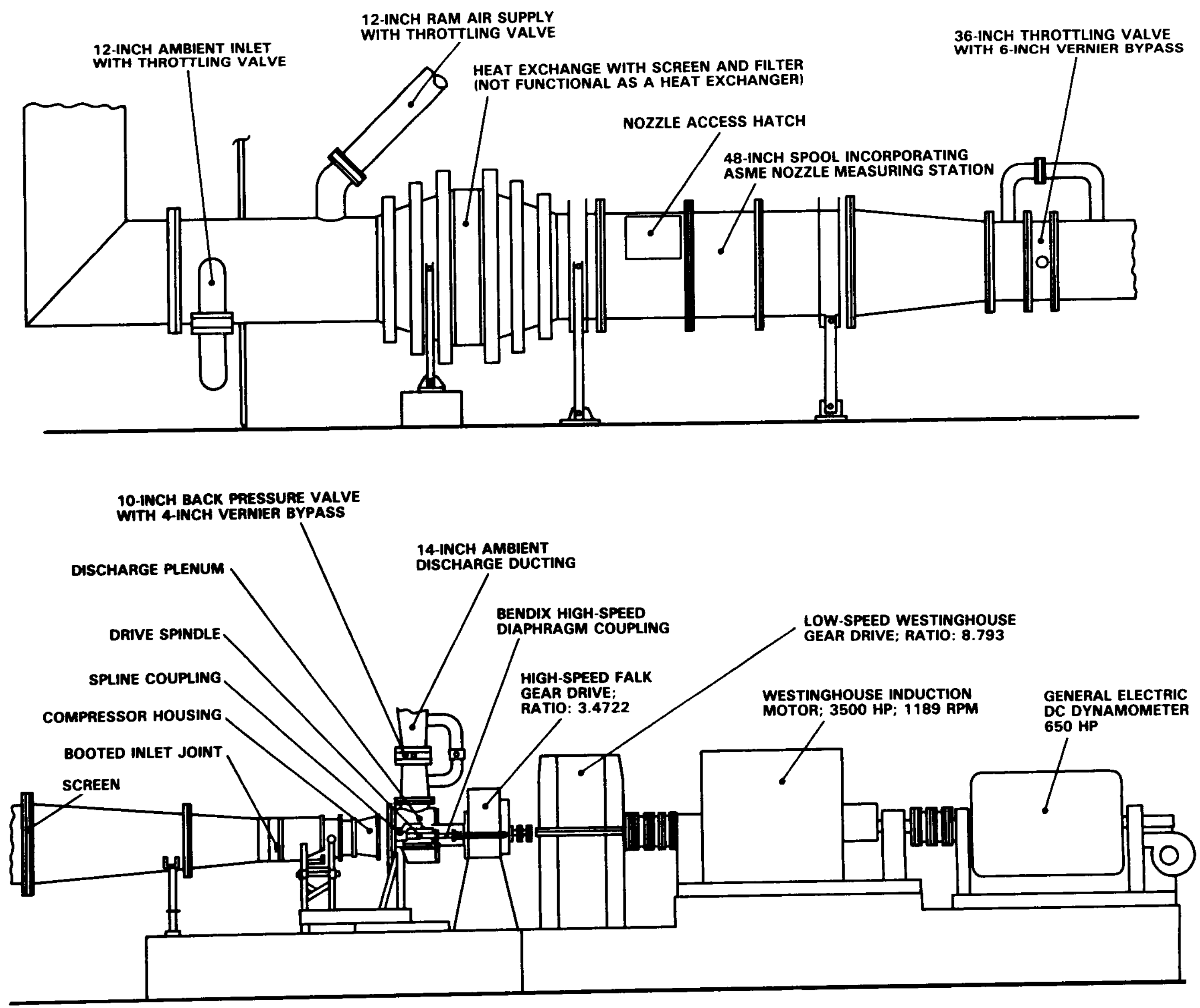
DATA ACQUISITION: Test data are automatically transmitted to the Sigma 8 computer located in the Engineering Building. Computed data are returned to the stand within 3 minutes and displayed on an alphanumeric scope. A total of 1000 data channels is available, 634 pressures, 360 temperatures, and 6 frequency channels. Strain gage vane connections are available.

CURRENT PROGRAMS: Full-scale fan/compressor component research and development.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Joseph A. Barlock, Manager, Experimental Test Equipment Engineering, East Hartford, CT. (203) 565-2091.

# 3500 HP COMPRESSOR TEST STAND



| Teledyne CAE | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 18 dia | **MAX. FLOW RATE: (lb/sec)** 22 | Group A |
| | **DATE BUILT/UPGRADED:** 1941/1970 | **PRESSURE LEVEL: (atm. max.)** 1.5 | |
| 3500 hp Compressor Test Stand | **REPLACEMENT COST:** Part of a $40M test center | **INLET TEMP. RANGE: (°F)** -60 – +110 | |
| | **OPERATIONAL STATUS:** 5 days per week | **SPEED RANGE: (rpm)** 39 000 | |
| | | **POWER LEVEL: (hp)** 3500 | |
| | Multistaged axial and centrifugal compressors and fans | | |

TESTING CAPABILITIES: The 3500 hp compressor test stand provides the capability for performance and structural testing of fans, centrifugal and multistage axial compressors, and combinations thereof up to a maximum of 3500 hp and 39 000 rpm. This is accomplished by changes in plenums, ducting, and gear sets as applicable. Inlet flows up to 60 lb/sec for fan testing can be accommodated with unconditioned air.

DATA ACQUISITION: Generally, 256 data channels are available. Data are processed by a Perkin Elmer 7/32 or 3210 computer. The results are displayed on a CRT and decwriter at the test site and are also stored on disc for more thorough post-test analysis.

CURRENT PROGRAMS: Performance evaluation of high-pressure ratio compressors and Vortex-controlled diffusers.

PLANNED IMPROVEMENTS: A 50 000 rpm gear set and increased inlet air heating capacity are being considered.

LOCAL INFORMATION CONTACT:

| | | | |
|---|---|---|---|
| Telydyne CAE | **COMPRESSOR COMPONENT RESEARCH FACILITY** | | **COMPARABLE FACILITIES** |
| | **COMPONENT SIZE: (in)** 10 dia | **MAX. FLOW RATE: (lb/sec)** 22 | Group A |
| | **DATE BUILT/UPGRADED:** 1941/1965 | **PRESSURE LEVEL: (atm. max.)** 1.5 | |
| 1400-1 and 1400-2 Compressor Test Stands | **REPLACEMENT COST:** Part of a $40M test center | **INLET TEMP. RANGE: (°F)** -65 – +235 | |
| | **OPERATIONAL STATUS:** 1 shift per day 5 days per week | **SPEED RANGE: (rpm)** 42 000; 70 000 | |
| | | **POWER LEVEL: (hp)** 1200; 420 | |
| | Multistaged axial and centrifugal compressor and fans | | |

TESTING CAPABILITIES: The 1400 hp No.1 and No. 2 compressor test stands provide the capability for testing small centrifugal and multistage axial compressors and fans in two separate test areas, each employing a 700 hp electric dynamometer. The dynamometers are located so that their shafts can be interconnected to produce up to 1400 hp in either test area. Currently available gear sets will provide 44 000 rpm at 1200 hp in No. 1, and 42 000 rpm at 1200 hp/70 000 rpm at 420 hp in No. 2. Inlet air and the compressor exhaust are connected to the facility environmental system to provide complete control of compressor inlet and exit conditions. Each test rig has its own control panel and data acquisition instrumentation.

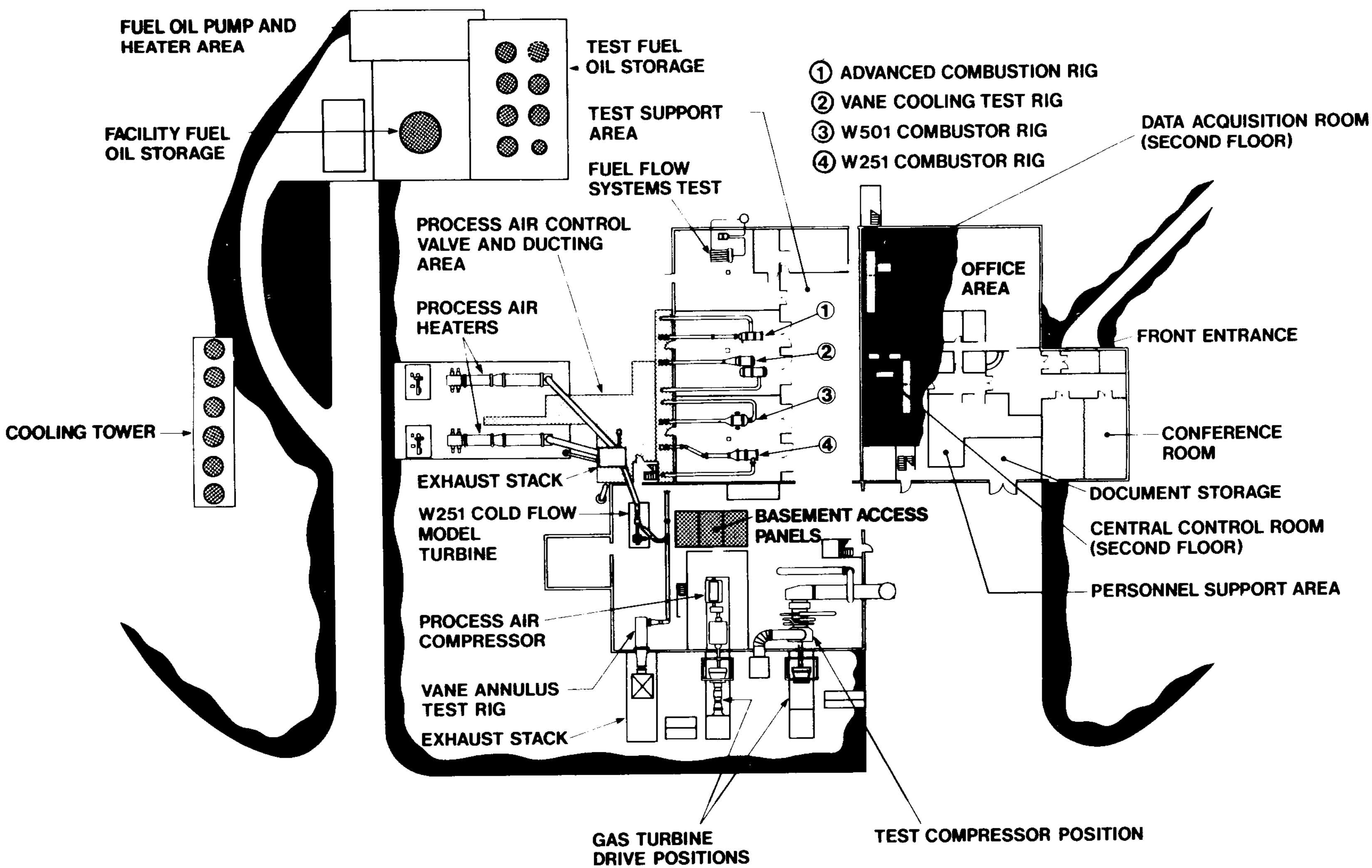
DATA ACQUISITION: Generally, 128 (expandable to 256) data channels are available. Data are processed by a Perkin Elmer 7/32 or 3210 computer. The results are displayed on a CRT and decwriter at the test site and are also stored on disc for more thorough post-test analysis.

CURRENT PROGRAMS: Performance evaluation of sweptback centrifugal compressors and high through flow fans.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

# COMBUSTION TURBINE DEVELOPMENT CENTER



| Westinghouse Combustion Turbine Systems Division, Concordville, PA | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** (in) Limited by power available | **MAX. FLOW RATE:** (lb/sec) | Group B |
| | **DATE BUILT/UPGRADED:** | **PRESSURE LEVEL:** (atm. max.) | |
| Combustion Turbine Development Center | **REPLACEMENT COST:** | **INLET TEMP. RANGE:** (°F) | |
| | **OPERATIONAL STATUS:** Not operational | **SPEED RANGE:** (rpm) 1200 – 4100 | |
| | | **POWER LEVEL:** (hp) 25 000 | |
| | Multistage fan or compressor components | | |

TESTING CAPABILITIES: This facility provides the capability of testing a large multistage compressor, fan, or similar component. Equipment in place includes the drive power turbine, supporting structure, and lube system. Inlet air coolers are available.

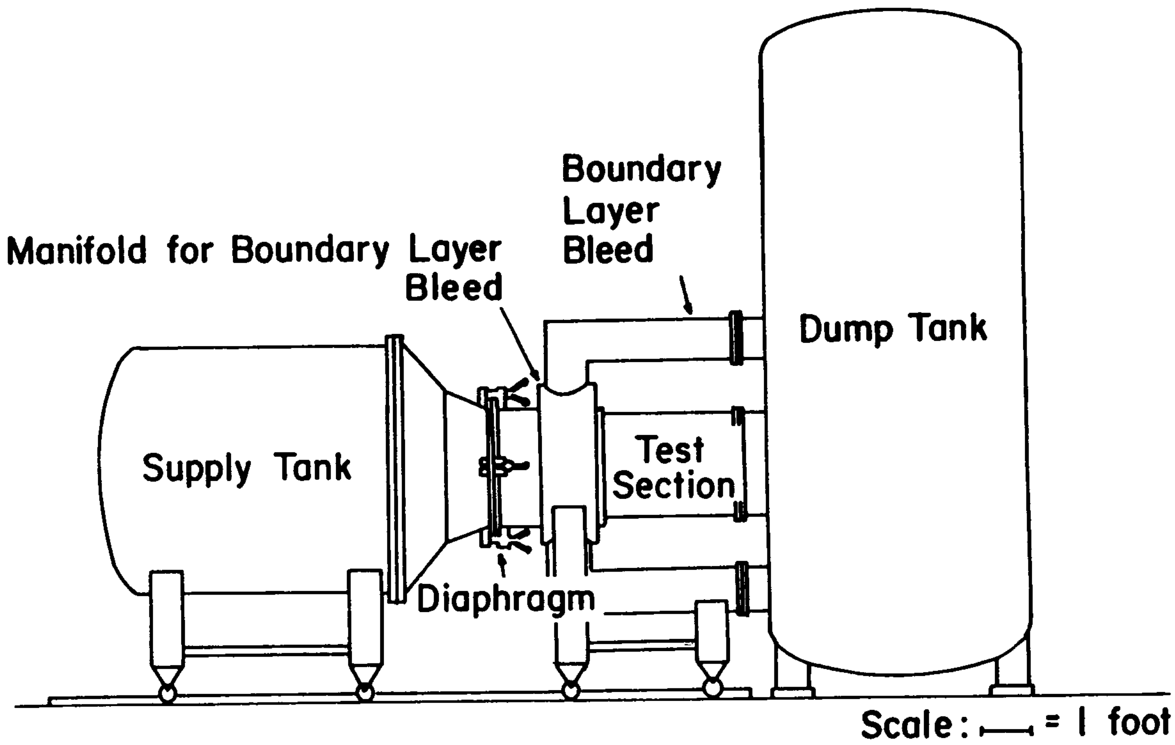
DATA ACQUISITION: Data are acquired, processed, recorded, and displayed by digital/analog system, including Honeywell tape recorders and Hewlett-Packard 1000F floating-point processor. Nominal system capacity is 800 channels; full data set every 6 seconds.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: C. D. Rambert, (215) 358-4769.

SCALE DRAWING OF BLOWDOWN COMPRESSOR FACILITY,
SIZED FOR 23.25-INCH DIAMETER ROTOR



| Massachusetts Institute of Technology | COMPRESSOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | COMPONENT SIZE: (in) 24 dia | MAX. FLOW RATE: (lb/sec) 100 scaled | Group A |
| | DATE BUILT/UPGRADED: 1970 | PRESSURE LEVEL: (atm. max.) 1 | |
| Blowdown Compressor Facility | REPLACEMENT COST: $1M | INLET TEMP. RANGE: (°F) 212 (max.) | |
| | OPERATIONAL STATUS: Up to 4 runs per day | SPEED RANGE: (rpm) 22 000 scaled | |
| | | POWER LEVEL: (hp) | |

TESTING CAPABILITIES: The facility provides 40 milliseconds of steady test time (corrected speed, weight flow, and pressure ratio constant to better than 1%) for the testing of single, high work, compressor stages. The scaled conditions listed above refer to the equivalent performance in air at standard conditions. Data are acquired with high-frequency response pressure and angle probes and fluorescent flow visualization.

DATA ACQUISITION: Direct on-line data acquisition system, 18 channels at up to 1 MHz/channel, 48 channels at up to 5 kHz/channel, 150 000 data points per test maximum.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: A. H. Epstein, Department of Aeronautics and Astronautics, (617) 253-2485.

| | | | |
|---|---|---|---|
| National Aerospace Laboratory, Japan | **COMPRESSOR COMPONENT RESEARCH FACILITY** | | **COMPARABLE FACILITIES** |
| | **COMPONENT SIZE: (in)** 200 shaft center from floor; 15 L | **MAX. FLOW RATE: (lb/sec)** | Group A |
| | **DATE BUILT/UPGRADED:** 1963 | **PRESSURE LEVEL: (atm. max.)** Ambient | |
| Fan/Compressor/ Turbine Facility 1600-kW DC Electric Dynamometer | **REPLACEMENT COST:** $1M | **INLET TEMP. RANGE: (°F)** Ambient | |
| | **OPERATIONAL STATUS:** 10 runs per year | **SPEED RANGE: (rpm)** 15 500 | |
| | | **POWER LEVEL: (hp)** 2160 | |
| | Fan, compressor, and turbine | | |

TESTING CAPABILITIES: This facility has the capacity of testing fans, compressors, and turbines at a maximum speed of 15 500 rpm and a maximum absorbable/driving power of 2160/2020 hp. No air supply system for turbine testings is currently available.

DATA ACQUISITION: No exclusive system is available.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Tadao Torisaki, Director of Aeroengine Division, (0422) 47-5911 (Japan).

<table>
<tr><td rowspan="2">Ihi Mizuho<br>Plant, Japan</td><td colspan="2">COMPRESSOR COMPONENT RESEARCH FACILITY</td><td>COMPARABLE FACILITIES</td></tr>
<tr><td>COMPONENT SIZE: (in) 34 dia x 40 L</td><td>MAX. FLOW RATE: (lb/sec) 310</td><td rowspan="6">Group B</td></tr>
<tr><td></td><td>DATE BUILT/UPGRADED: 1980</td><td>PRESSURE LEVEL: (atm. max.) 2</td></tr>
<tr><td rowspan="4">Large-Scale<br>Aero Engine<br>Compressor<br>Facility</td><td>REPLACEMENT COST: $3.5M</td><td>INLET TEMP. RANGE: (°F) Ambient</td></tr>
<tr><td rowspan="2">OPERATIONAL STATUS:<br>1 shift per day<br>4 – 5 runs per month</td><td>SPEED RANGE: (rpm) 13 000</td></tr>
<tr><td>POWER LEVEL: (hp) 18 000</td></tr>
<tr><td colspan="2">Full-scale single- or two-stage fan</td></tr>
</table>

TESTING CAPABILITIES: This facility has the capability of full-scale and large bypass ratio fan rotating test at a maximum pressure ratio of 3 atm. It is capable of testing compressors up to 18 000 hp with maximum speed of 13 000 rpm.

DATA ACQUISITION: Number of input points: 380 pressure measurement points, 120 temperature measurement points.

CURRENT PROGRAMS: High-loaded, high-efficiency single-stage fan rotating test began in 1983.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: K. Murashima, Manager, Research and Development Department, (0425) 56-7241 (Japan).

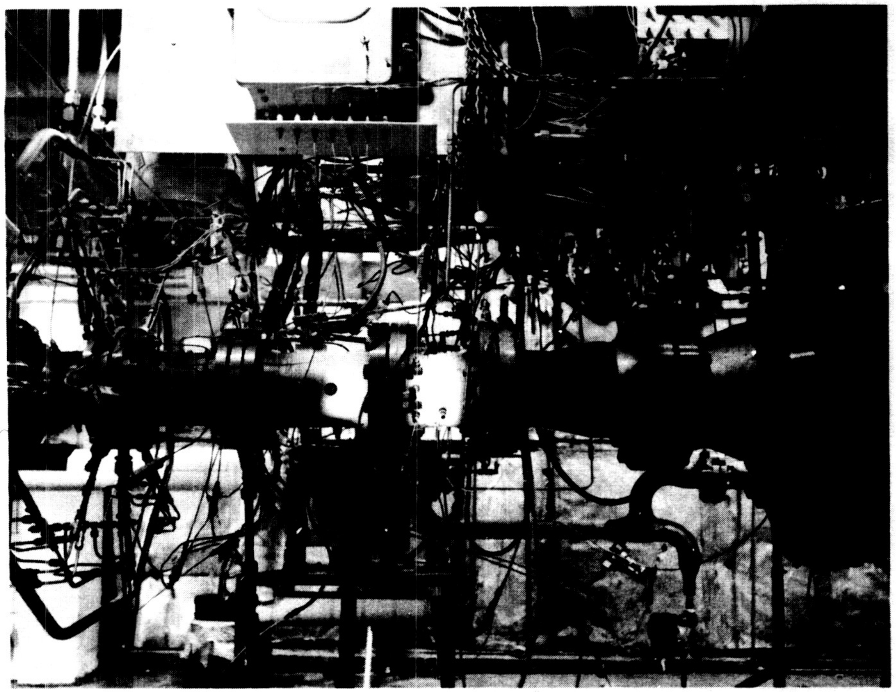
## COMBUSTOR RESEARCH FACILITIES

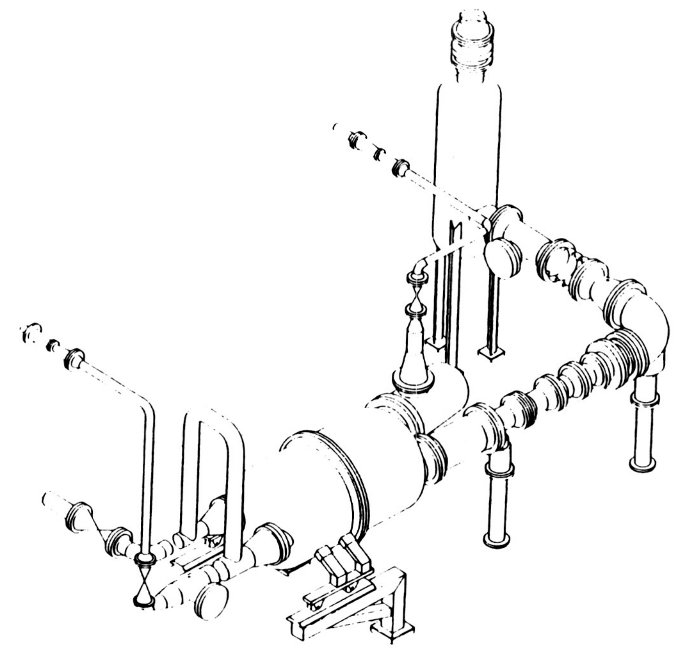
| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) | Group |
|---|---|---|---|---|---|---|---|
| | U.S. NASA | | | | | | |
| | Lewis Research Center | | | | | | |
| 152 | Low-Pressure Combustor Facilities | A: 10<br>B: 3 | N/A<br>N/A | 1100<br>1800 | 10<br>10 | N/A<br>N/A | B |
| 153 | Medium-Pressure Combustor Facilities | 20 | N/A | Ambient - 1100 | 30 | N/A | B |
| 154 | High-Pressure Combustor Facility (HPC) | 200 | N/A | Ambient - 850 | 20 operational<br>40 standby | N/A | B |
| | U.S. DOD | | | | | | |
| | Wright Aeronautical Labs | | | | | | |
| 155 | Combustion Research Tunnel | 7 ½ | N/A | Ambient | Atmospheric | N/A | A |
| | U.S. INDUSTRY | | | | | | |
| | Garrett Turbine Engine Company | | | | | | |
| 156 | C-100 Combustion Test Facility | 18 | N/A | 60 - 2000 | 20 | N/A | B |
| | Pratt & Whitney | | | | | | |
| 157 | High-Pressure Combustor Lab | 100 | N/A | 450 to 1200 | 44.2 | N/A | C |
| | Southwest Research Institute | | | | | | |
| 158 | Army Fuels and Lubricants Lab, Combustor Test Facility | 2.5 | N/A | -65 - +1500 | 16 | N/A | B |

## COMBUSTOR RESEARCH FACILITIES

| Page Number | Location and Facility Description | Max. Flow Rate (lb/sec) | Max. Power (hp) | Temperature (°F) | Pressure (atm. max) | Speed (rpm) | Group |
|---|---|---|---|---|---|---|---|
| | **U.S. INDUSTRY** | | | | | | |
| | Telydyne CAE | | | | | | |
| 159 | Combustor Cell | 4; 22 | N/A | -65 - +500 | 6; 1.7 | N/A | A |
| | Westinghouse Combustion Turbine Systems | | | | | | |
| 160 | Full-Scale Cylindrical Reverse Flow Rig | 90 | N/A | 900 | 20 | N/A | B |
| | **JAPAN** | | | | | | |
| | Ihi Mizuho Plant | | | | | | |
| 161 | Medium-Pressure Combustor Facility (MPC) | 24 | N/A | 180 - 780 | 7 | N/A | A |
| | National Aerospace Laboratory | | | | | | |
| 162 | High-Pressure Annular Combustor Test Facility | 30 | N/A | 730 | 9 | N/A | A |
| 163 | High-Pressure Combustor Test Facility | 8.8 | N/A | Ambient - 850 | 50 | N/A | C |

# LOW-PRESSURE COMBUSTOR FACILITIES





| NASA–Lewis Research Center, Cleveland, OH | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** A: 8 B: 4 | **MAX. FLOW RATE: (lb/sec)** A: 10 B: 3 | |
| | **DATE BUILT/UPGRADED:** 1974 | **PRESSURE LEVEL: (atm. max.)** A: 10 B: 10 | |
| Low-Pressure Combustor Facilities | **REPLACEMENT COST:** $2M | **INLET TEMP. RANGE: (°F)** A: 1100 B: 1800 | |
| | **OPERATIONAL STATUS:** Inactive | **SPEED RANGE: (rpm)** A: N/A B: N/A | |
| | | **POWER LEVEL: (hp)** A: N/A B: N/A | |
| | Two test cell positions in CRL-11 | | |

TESTING CAPABILITIES: These facilities are utilized for testing can-type combustors, sector combustors, or fundamental flame tubes to study combustor phenomena. Inlet air flows of up to 10 lb/sec at pressures up to 10 atm at realistic inlet temperatures are available. Fixed and rotating exhaust sampling systems are available with on-line gas analysis capability. Pressure, temperature, air, and fuel flows are measured (<400 data channels available).

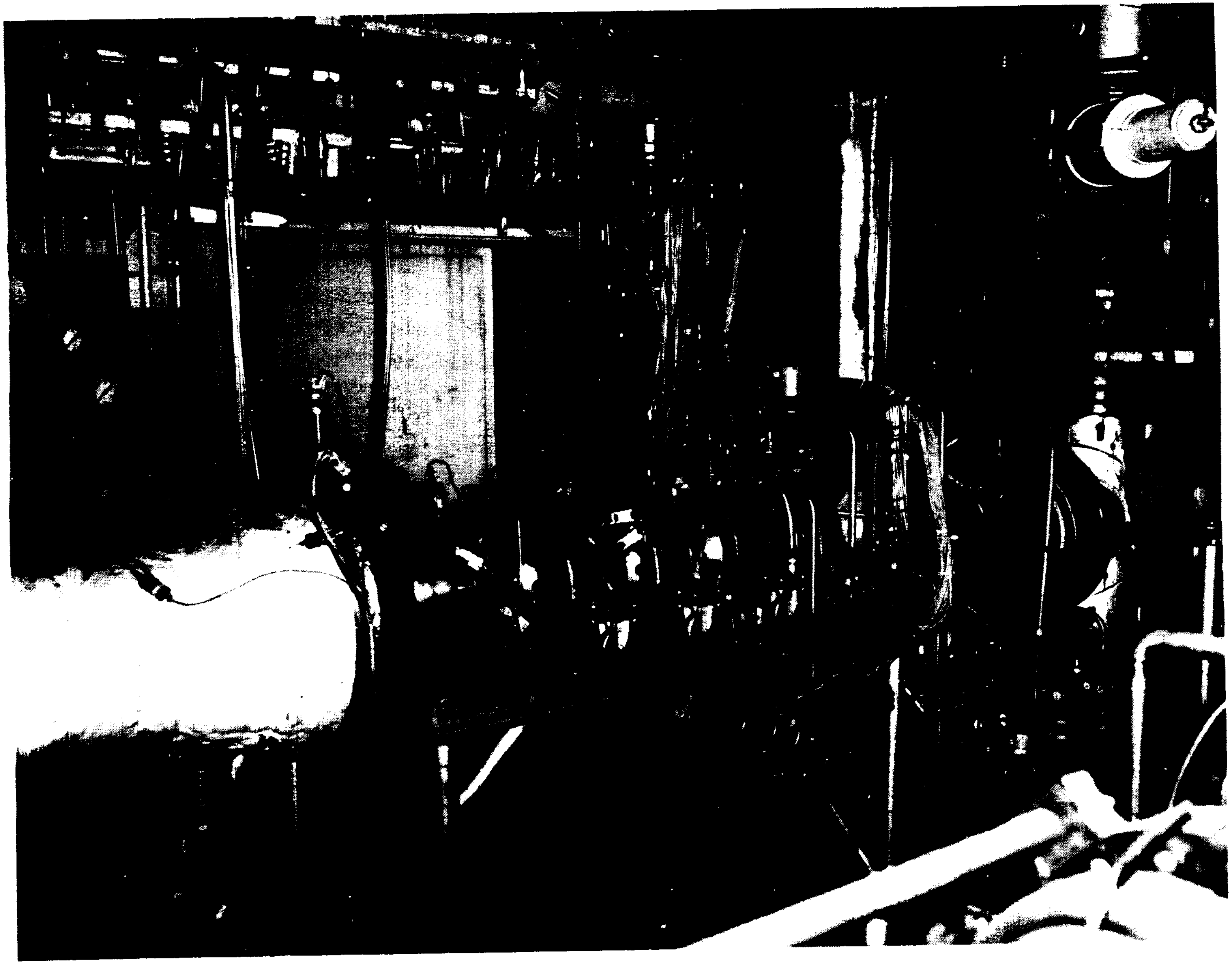
DATA ACQUISITION: Research data points are recorded by means of a central data collector system (ESCORT II) and can be processed on the IBM 370 central computer for control room display or for post-test analysis.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# MEDIUM-PRESSURE COMBUSTOR FACILITIES



| NASA–Lewis Research Center, Cleveland, OH | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE:** 18 dia **(in)** | **MAX. FLOW RATE:** 20 **(lb/sec)** | Group B |
| | **DATE BUILT/UPGRADED:** 1971/1980 | **PRESSURE LEVEL:** 30 **(atm. max.)** | |
| Medium-Pressure Combustor Facilities | **REPLACEMENT COST:** $7M | **INLET TEMP. RANGE:** Ambient – 1100 **(°F)** | |
| | **OPERATIONAL STATUS:** 2 – 3 runs per week; 1 shift per day | **SPEED RANGE:** N/A **(rpm)** | |
| | | **POWER LEVEL:** N/A **(hp)** | |
| | Full annular can-type and section combustors | | |

TESTING CAPABILITIES: These facilities are capable of testing various combustor types. Simulated engine conditions for research testing are provided by means of direct connection to a central air system with 30 atm pressure capability. Inlet air is preheated to 1100°F by means of non-vitiating heat exchangers. Pressures and temperature measurements are made with fixed and rotating probes, and on-line exhaust gas analysis is provided (380 temperature channels, 80 pressure channels, 6 high-response pressure channels, plus 24 fuel and airflow rate channels).

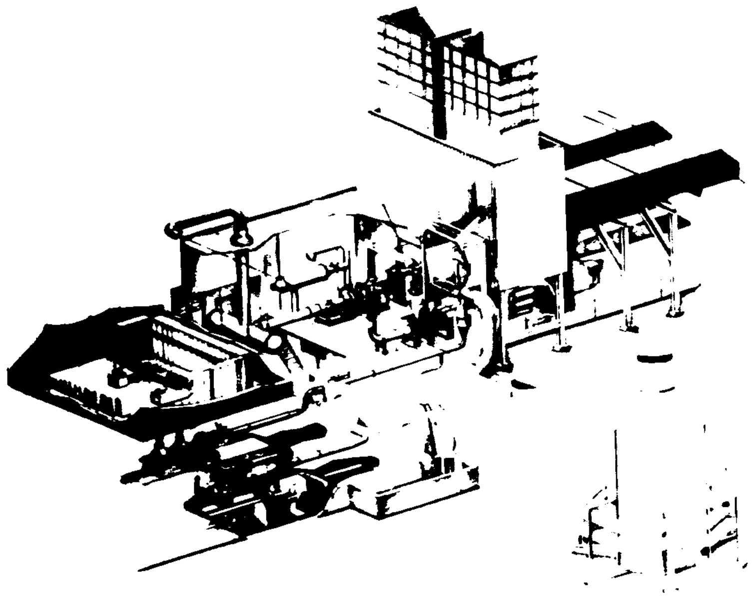
DATA ACQUISITION: Research data points are recorded by means of a central data collector system (ESCORT II) and are processed on the IBM 370 central computer for control room display or post-test analysis.

CURRENT PROGRAMS: Fuel vaporization studies, high-temperature-rise combustor for studies, and ceramic matrix liner studies.

PLANNED IMPROVEMENTS: None.

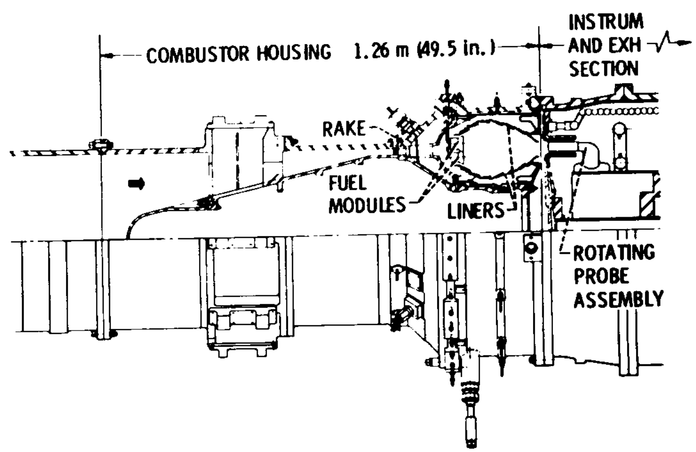
LOCAL INFORMATION CONTACT: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.

# HIGH-PRESSURE COMBUSTION FACILITY



PERSPECTIVE VIEW OF HIGH-PRESSURE FACILITY

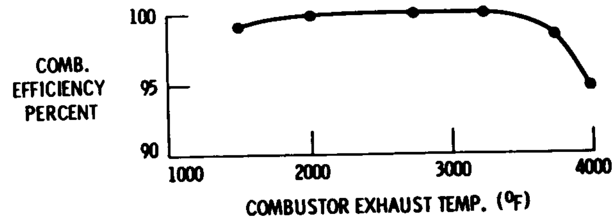
COMBUSTION SYSTEM FOR HIGH-PRESSURE FACILITY




## COMBUSTOR OPERATING CONDITIONS

| INLET | EXHAUST |
|---|---|
| 75 - 600 psia | 70 - 560 |
| 100 - 1150° F | 1500 - 4000 |
| 25 - 180 lb/sec | 25 - 192 |

COMBUSTOR TEST DATA



| | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| NASA–Lewis Research Center, Cleveland, OH | **COMPONENT SIZE: (in)** 20 dia x 30 L | **MAX. FLOW RATE: (lb/sec)** 200 | Group B |
| | **DATE BUILT/UPGRADED:** 1979 | **PRESSURE LEVEL: (atm. max.)** 20 operational (40 standby) | |
| High-Pressure Combustor Facility (HPC) | **REPLACEMENT COST:** $15M | **INLET TEMP. RANGE: (°F)** Ambient – 850 | |
| | **OPERATIONAL STATUS:** Inactive | **SPEED RANGE: (rpm)** N/A | |
| | | **POWER LEVEL: (hp)** N/A | |
| | Full annular combustor | | |

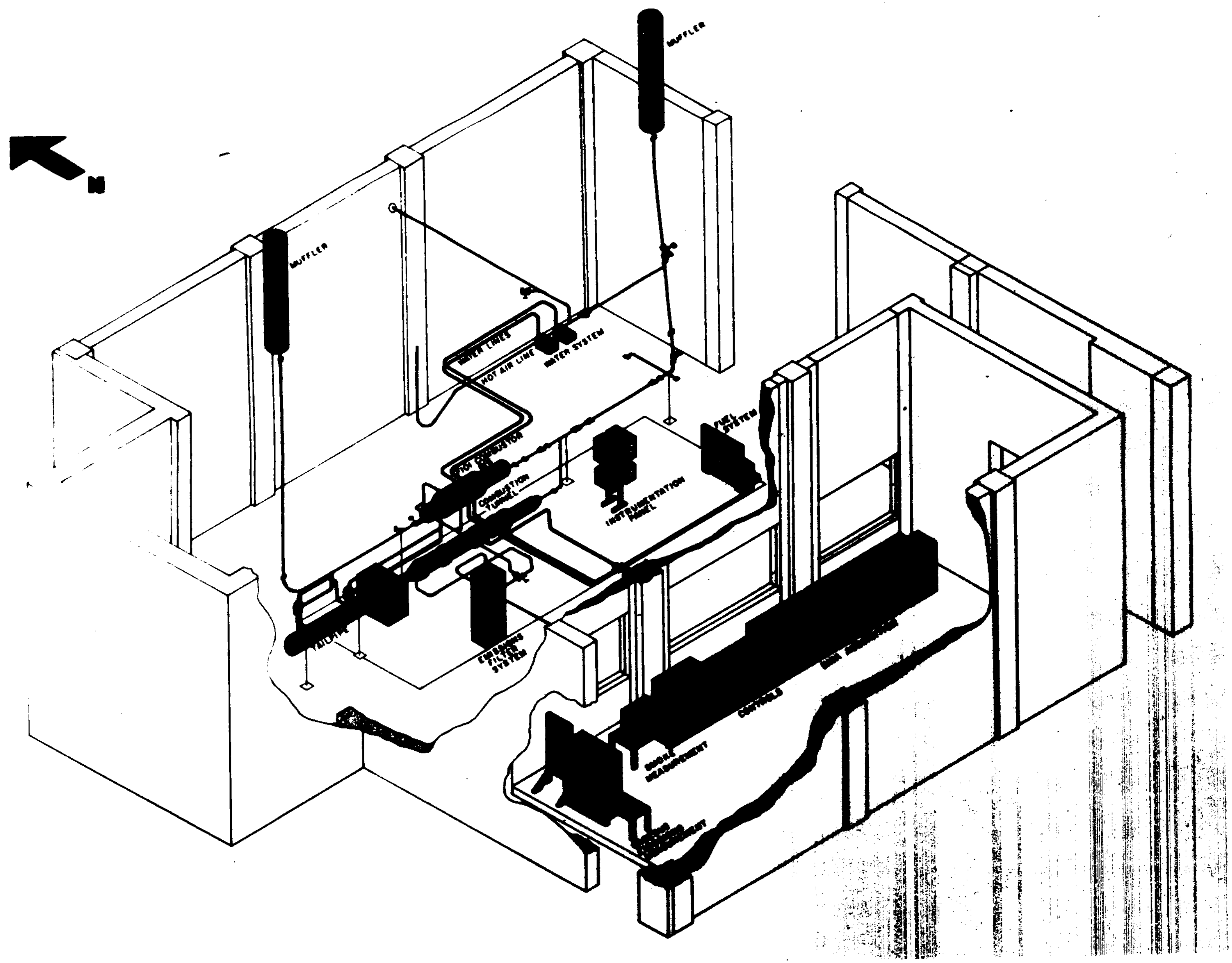
<u>TESTING CAPABILITIES</u>: This facility has the capability of eventually testing full annular combustors at a maximum pressure level of 40 atm., an inlet temperature of 1150°F, and a flow rate of 187 lb/sec. Operation is currently limited to the lower values shown above. Fully automated facility control and research data acquisition is achieved by means of five dedicated PDP-11 minicomputers that afford precise setting of operating condition and data replication.

<u>DATA ACQUISITION</u>: Full annular exhaust rotating rake system, 340 total data channels, fully automated data acquisition, data recording by means of central data collector (ESCORT II), data processing by means of central IBM 370 computer.

<u>CURRENT PROGRAMS</u>: None.

<u>PLANNED IMPROVEMENTS</u>: None.

<u>LOCAL INFORMATION CONTACT</u>: David Bowditch, Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6123, FTS 8-294-6123; Lawrence E. Macioce, Deputy Chief, Aeropropulsion Facilities & Experiments Div., (216) 433-4000, ext. 6884, FTS 8-294-6884.


N
MUFFLER
MUFFLER
WATER LINES
HOT AIR LINE
WATER SYSTEM
FUEL SYSTEM
COMBUSTION TUNNEL
INSTRUMENTATION PANEL
EMISSIONS FILTER SYSTEM
CONTROLS
SMOKE MEASUREMENT

| | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| DOD–AFWAL<br>Aero Propulsion<br>Laboratory | **COMPONENT SIZE:** 10 dia x 48 L<br>**(in)** | **MAX. FLOW RATE:** 7½<br>**(lb/sec)** | Group A |
| | **DATE BUILT/UPGRADED:** 1979/1984 | **PRESSURE LEVEL:** Atmospheric<br>**(atm. max.)** | |
| Combustion<br>Research Tunnel | **REPLACEMENT COST:** $1M | **INLET TEMP. RANGE:** Ambient<br>**(°F)** | |
| | **OPERATIONAL STATUS:**<br>1 – 2 runs per week<br>1 shift per day | **SPEED RANGE:** N/A<br>**(rpm)** | |
| | | **POWER LEVEL:** N/A<br>**(hp)** | |

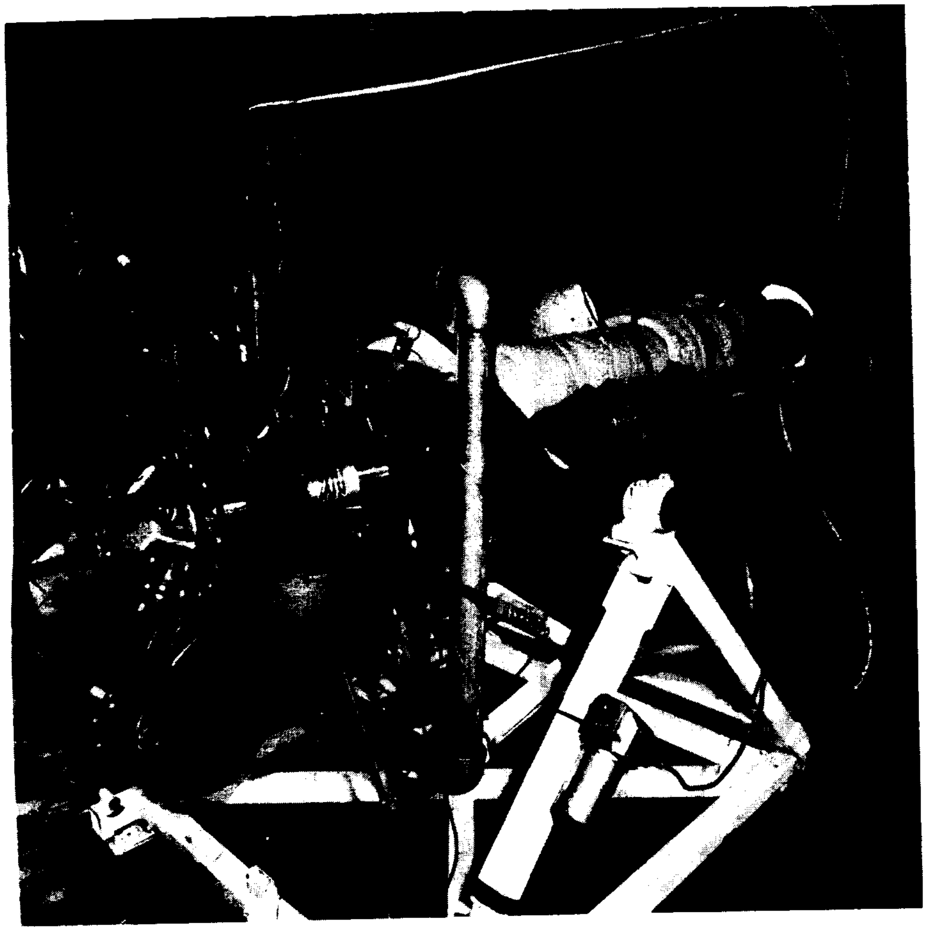
TESTING CAPABILITIES: This facility has the capability for testing experimental combustors at flow rates up to 7-1/2 lb/sec at 1 atmosphere pressure. Quartz windows provide optical access downstream of the combustor, allowing the use of a wide range of optical diagnostics as well as conventional intrusive probes. A dedicated computer allows rapid data acquisition.

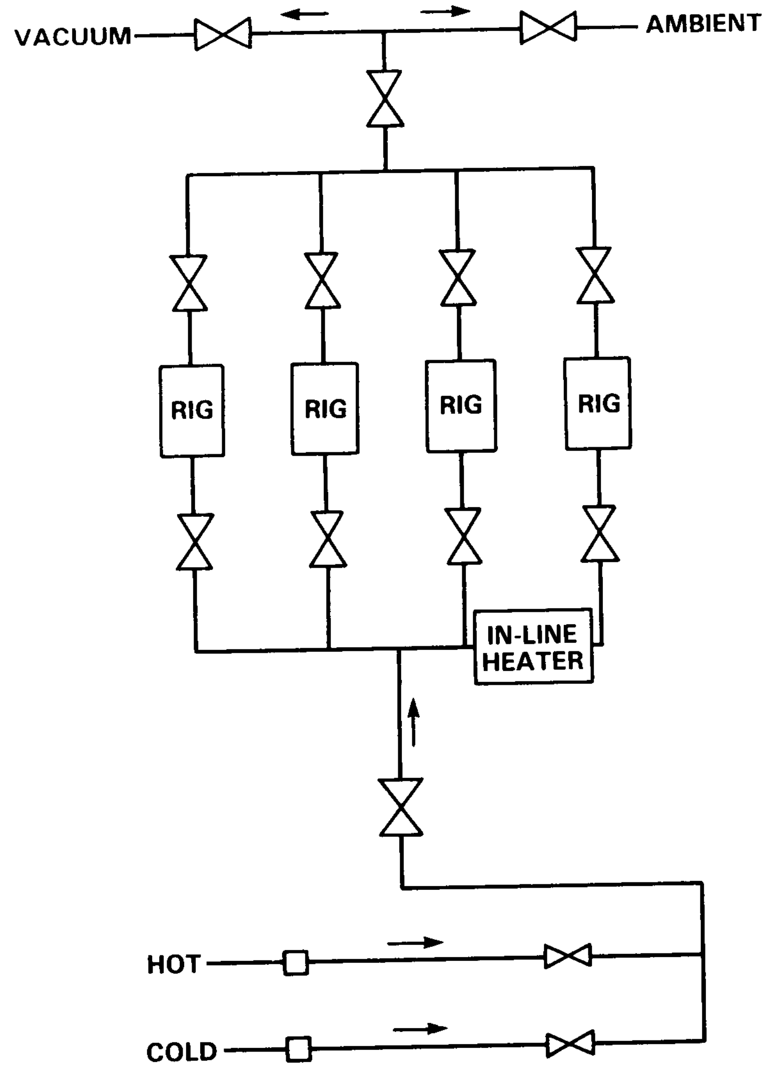
DATA ACQUISITION: Gas sampling and thermocouple probes are available as well as 2-D laser Doppler anemometer and a coherent anti-Stokes Raman spectrometer. These are controlled by a dedicated MODCOMP classic computer. High-speed cine photography can also be used to obtain visual recordings of the combustion zone.

CURRENT PROGRAMS: A bluff-body coaxial jet combustor is being tested. Flow-field measurements of temperatures, velocities, and specie concentrations are being made.

PLANNED IMPROVEMENTS: Provide inlet air temperatures up to 800°F, pressures to 4 atm, and flow rates up to 30 lb/sec.

LOCAL INFORMATION CONTACT:




VACUUM
AMBIENT
RIG
RIG
RIG
RIG
IN-LINE HEATER
HOT
COLD

| | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| Garrett Turbine Engine Company, Phoenix, AZ | **COMPONENT SIZE: (in)** 60 dia x 84 L | **MAX. FLOW RATE: (lb/sec)** 18 | Group B |
| | **DATE BUILT/UPGRADED:** 1957 continually upgraded | **PRESSURE LEVEL: (atm. max.)** 20 | |
| C-100 Combustion Test Facility | **REPLACEMENT COST:** $500K | **INLET TEMP. RANGE: (°F)** 60 to 2000 | |
| | **OPERATIONAL STATUS:** 3 shifts per day | **SPEED RANGE: (rpm)** N/A | |
| | | **POWER LEVEL: (hp)** N/A | |
| | | | |

TESTING CAPABILITIES: This facility provides the capability of research, development, and product improvement testing. Capabilities include testing for pattern factor, pressure losses, lean stability, ignition parameters (sea level to altitude), bleed flow effects, emissions analysis, and cyclic testing of high-temperature components. Gaseous and liquid fuels are available.

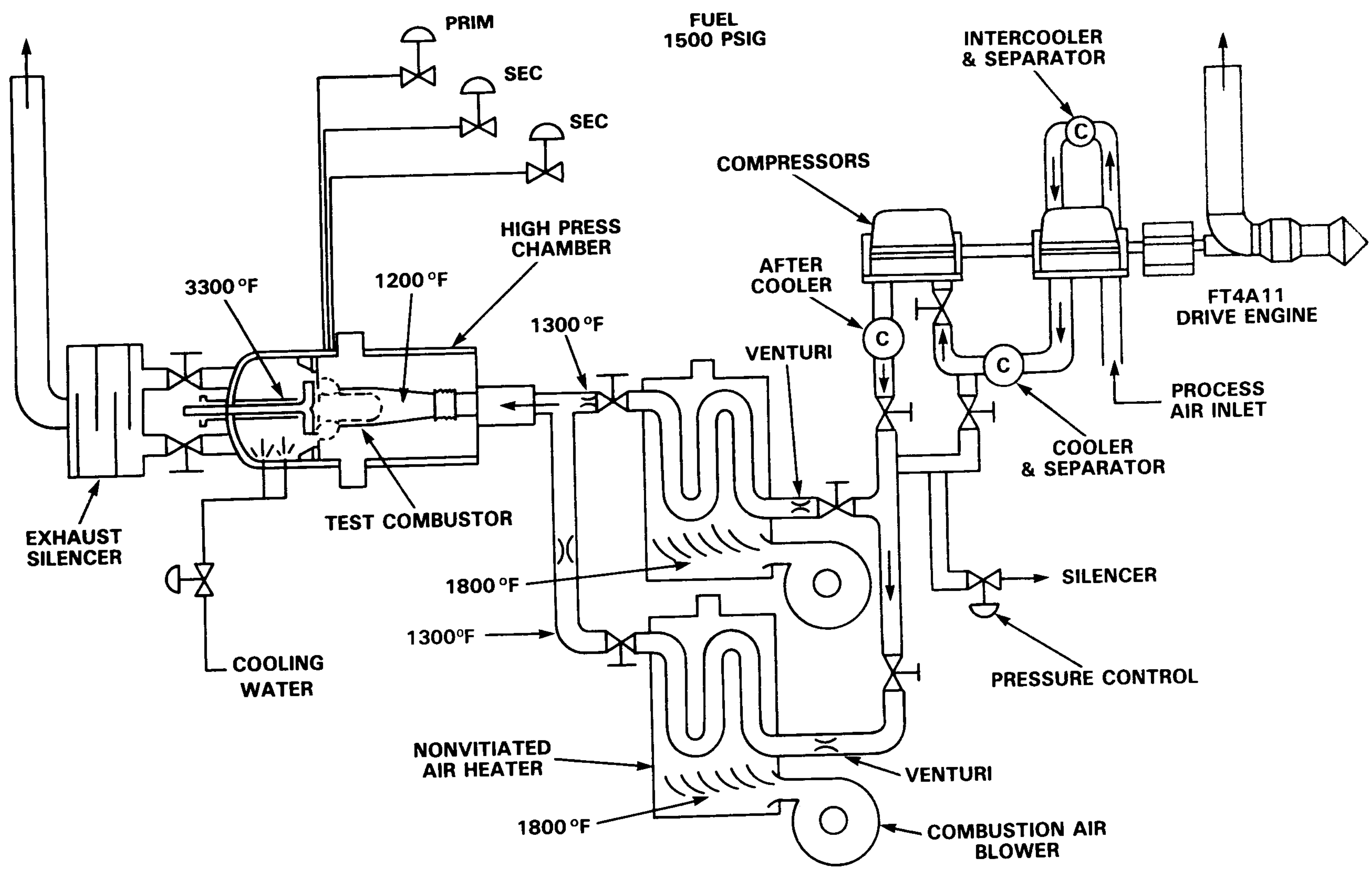
DATA ACQUISITION: Data are recorded by computer via the central data acquisition system. "On-line" performance calculations are provided at the test cell on CRT.

CURRENT PROGRAMS: Development and research programs.

PLANNED IMPROVEMENTS: Continual update.

LOCAL INFORMATION CONTACT: Robert L. Olive, Engineering Laboratory, (602) 231-4913.

# HIGH-PRESSURE COMBUSTOR LABORATORY X-960 STAND FACILITY SCHEMATIC



| United Technologies<br><br>Pratt & Whitney Aircraft | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 72 dia x 8 – 10 L | **MAX. FLOW RATE: (lb/sec)** 100 | Group C |
| | **DATE BUILT/UPGRADED:** | **PRESSURE LEVEL: (atm. max.)** 44.2 | |
| High Pressure Combustor Laboratory | **REPLACEMENT COST:** $24M | **INLET TEMP. RANGE: (°F)** 450 – 1200 | |
| | **OPERATIONAL STATUS:** Operational | **SPEED RANGE: (rpm)** N/A | |
| | | **POWER LEVEL: (hp)** N/A | |
| | Fuel up to 44 GPM @ 1500 psia and 300°F | | |

TESTING CAPABILITIES: The X-960 stand, the high pressure combustion laboratory, is a complete facility dedicated to development testing of gas turbine engine combustors at conditions simulating those encountered in full engine operation. The laboratory includes: (1) a compressed air system; (2) air heaters; (3) test chamber; (4) data acquisition; (5) rig supervisory control; and (6) fuel, water, and electric services.

DATA ACQUISITION: Test data are transmitted directly to a Univac computer located in the Engineering Building. Data are returned within 3 minutes and are displayed on alphanumeric scopes. A total of 1607 data channels is available, 800 pressures, 800 temperatures, and 7 frequency channels. An emissions sampling system receives up to 30 samples and analyzes them on the stand. A rig supervisory control (RSC) monitors and controls airflow, inlet temperature and pressure, fuel/air ratio, and balance air.

CURRENT PROGRAMS: Combustor research and development.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Joseph A. Barlock, Manager, Experimental Test Equipment Engineering, East Hartford, CT, (203) 565-2091.

| | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| Southwest Research Institute | **COMPONENT SIZE: (in)** 2 – 6 dia | **MAX. FLOW RATE: (lb/sec)** 2.5 | Group B |
| | **DATE BUILT/UPGRADED:** 1975 | **PRESSURE LEVEL: (atm. max.)** 16 | |
| Army Fuels and Lubricants Laboratory, Combustor Test Facility | **REPLACEMENT COST:** $400K | **INLET TEMP. RANGE: (°F)** -65 – +1500 | |
| | **OPERATIONAL STATUS:** Operation ½ year, 1 shift | **SPEED RANGE: (rpm)** N/A | |
| | | **POWER LEVEL: (hp)** N/A | |
| | Three combustors are available for tests: a T63; a disc-in-duct research combustor; and a Phillips 2-inch diameter research combustor | | |

TESTING CAPABILITIES: This facility has high-temperature and high-pressure air supply capabilities, which allow testing over a broad range of conditions. It has been used mainly to study fuel effects on evaporation and combustion. Very detailed fuel analysis capabilities including many ASTM tests are available, as well as fuel-blending facilities. In addition to standard instrumentation for measuring temperature, pressure, and air and fuel flow rates, special instrumentation includes drop-sizing apparatus modified for use in evaporating flows, two-phase probes for measuring fuel vapor in sprays, radiometers for flame emissions measurements, and optical equipment for flame temperature measurements. Instrumentation also is available for emissions measurements for both gases and particulates. Air velocities may be measured in unseeded flows using a laser Doppler anemometer with a photon correlator.

DATA ACQUISITION: Fifty channels of data are recorded using a 50-channel scanner coupled to a digital voltmeter and a Hewlett-Packard 9820 programmable calculator. The calculator handles all of the data reduction and any necessary calculations (e.g., combustion efficiency, flow factor, and exhaust emissions coefficients).

CURRENT PROGRAMS: Two programs are currently under way to study the effects of fuel properties and air conditions on evaporation of fuels. Drop-size measurements and two-phase probe results are being used to verify a computer model for spray evaporation.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Lee G. Dodge, Department of Energy Conversion and Combustion Technology, (512) 684-5111, ext. 3251; David W. Naegeli, Department of Energy Conversion and Combustion Technology, (512) 684-5111, ext. 2574; Clifford A. Moses, Department of Energy Conversion and Combustion Technology, (512) 684-5111, ext. 2370.

| | | | |
|---|---|---|---|
| Teledyne CAE | **COMBUSTOR COMPONENT RESEARCH FACILITY** | | **COMPARABLE FACILITIES** |
| | **COMPONENT SIZE: (in)** 30 | **MAX. FLOW RATE: (lb/sec)** 4/20 | Group A |
| | **DATE BUILT/UPGRADED:** 1943/1975 | **PRESSURE LEVEL: (atm. max.)** 6/1.7 | |
| Combustor Cell | **REPLACEMENT COST:** Part of a $40M test center | **INLET TEMP. RANGE: (°F)** -65 – 500 | |
| | **OPERATIONAL STATUS:** 1 – 5 runs per week, 1 shift per day | **SPEED RANGE: (rpm)** N/A | |
| | | **POWER LEVEL: (hp)** N/A | |

TESTING CAPABILITIES: These facilities provide the capability of evaluating fuels and the performance of both 2D or full annular combustors. Combustor test rigs are adaptable for studying either nozzle or slinger-type fuel injection systems.

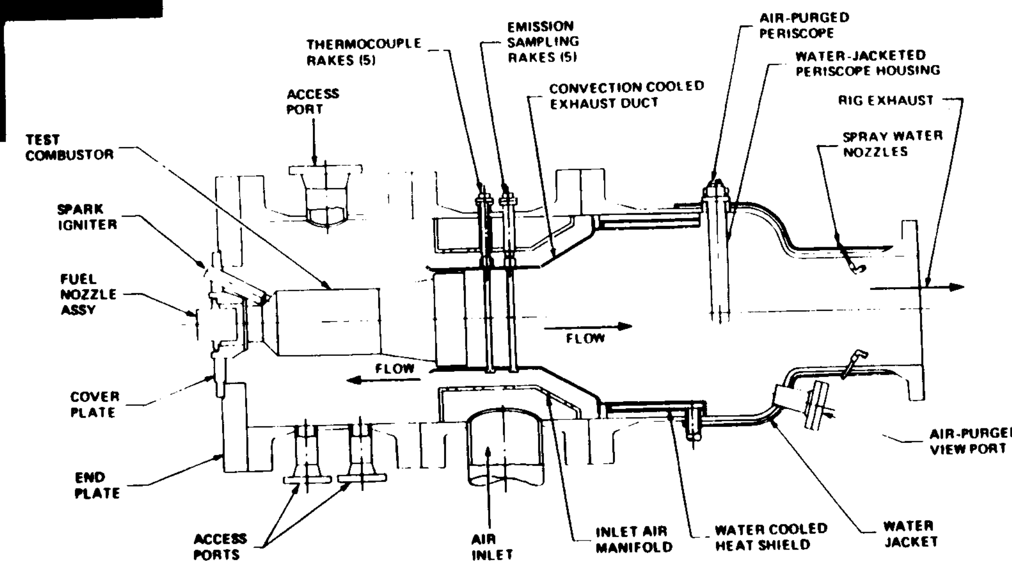
DATA ACQUISITION: Generally, 128 (expandable to 256) data channels are available. Data are processed by a Perkin Elmer 7/32 or 3210 computer. The results are displayed on a CRT and decwriter at the test site and are also stored on disc for more thorough analysis.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT:

# FULL-SCALE CYLINDRICAL REVERSE FLOW RIG



| Westinghouse Combustion Turbine Systems Division, Concordville, PA | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 15 dia nominal | **MAX. FLOW RATE: (lb/sec)** 90 | Group B |
| | **DATE BUILT/UPGRADED:** 1976 – 1982 | **PRESSURE LEVEL: (atm. max.)** 20 | |
| Full-scale Cylindrical Reverse Flow Rig | **REPLACEMENT COST:** | **INLET TEMP. RANGE: (°F)** 900 | |
| | **OPERATIONAL STATUS:** 1 shift per day | **SPEED RANGE: (rpm)** N/A | |
| | | **POWER LEVEL: (hp)** N/A | |
| | Facilities consist of three combustor rigs located in Combustion Turbine Development Center, Concordville, PA | | |

TESTING CAPABILITIES: These facilities provide the capability of testing full-scale gas turbine combustors at full engine operating conditions. A fuel storage and forwarding system provides a range of liquid fuels at maximum conditions of 25 GPM, 1500 psi, and 350°F. Maximum combustion temperature as limited by the test hardware and instrumentation. The test rig can be adapted to various geometry combustors. Water/steam injection is available.

DATA ACQUISITION: Data are acquired, processed, recorded, and displayed by digital/analog system, including Honeywell tape recorders and Hewlett-Packard 1000F floating-point processor. Nominal system capacity is 800 channels; full data set every 6 seconds. A full range of exhaust constituent measurements can be obtained with on-line analyzer and recorders.

CURRENT PROGRAMS: Combustor R&D, including increased firing temperature, improved wall cooling, reduced emissions, and alternative fuel capabilities (including synthetic).

PLANNED IMPROVEMENTS: As required for scheduled programs.

LOCAL INFORMATION CONTACT: C. D. Rambert, (215) 358-4769.

| Ihi Mizuho Plant, Japan | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **COMPONENT SIZE: (in)** 18 dia x 9 L | **MAX. FLOW RATE: (lb/sec)** 24 | Group A |
| | **DATE BUILT/UPGRADED:** 1979 | **PRESSURE LEVEL: (atm. max.)** 7 | |
| Medium-Pressure Combustor Facility (MPC) | **REPLACEMENT COST:** $3.5M | **INLET TEMP. RANGE: (°F)** 180 – 780 | |
| | **OPERATIONAL STATUS:** 1 shift per day<br>300 hr per year | **SPEED RANGE: (rpm)** N/A<br>**POWER LEVEL: (hp)** N/A | |
| | Full annular combustor | | |

TESTING CAPABILITIES: This facility has the capability of full annular combustor testing at a maximum pressure level of 7 atm, flow rate of 24 lb/sec, and inlet air temperature range of 180° to 780°F.

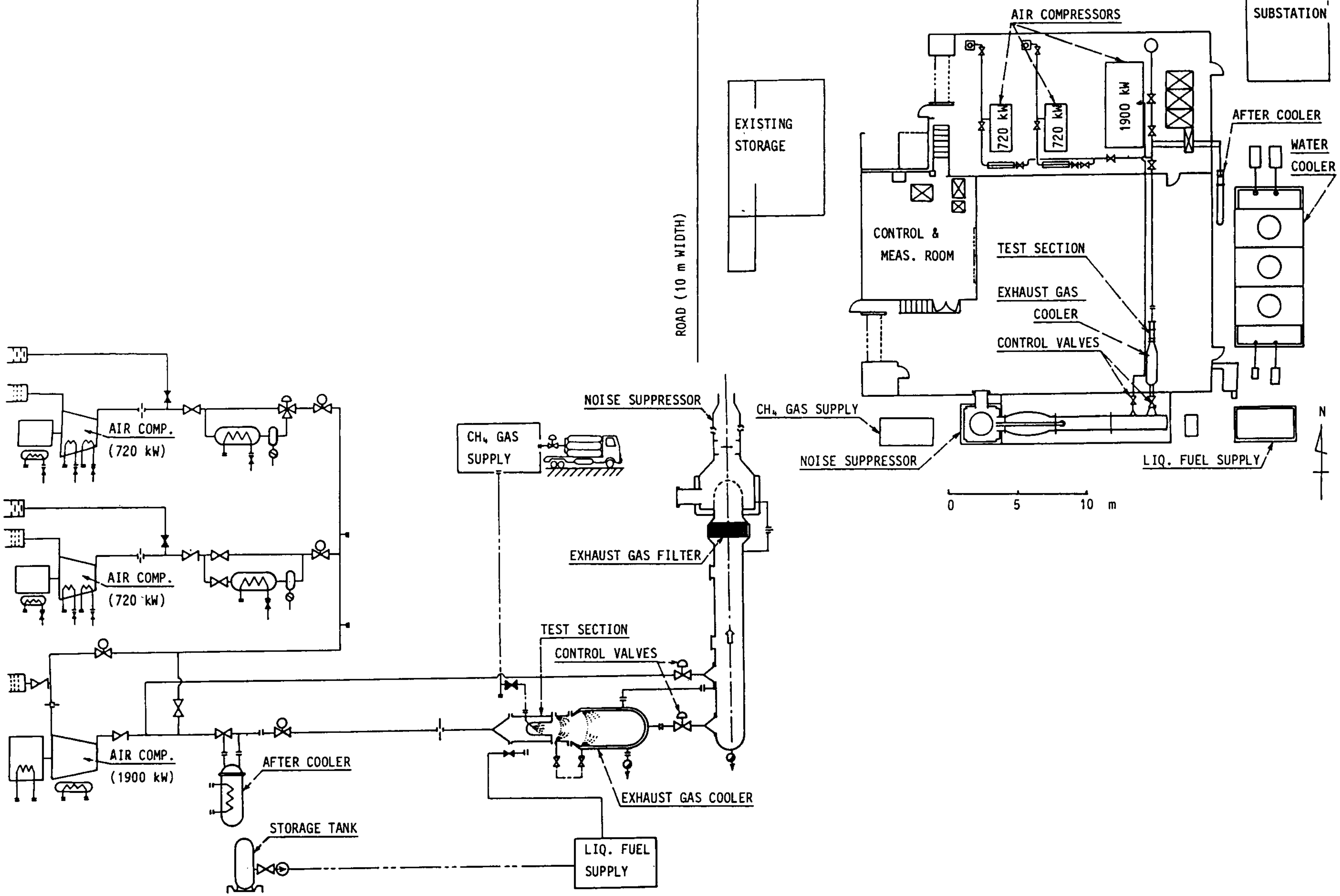
DATA ACQUISITION: Full annular exhaust rotating rake system, 80 total data channels, and fully automated data acquisition, data recording, and data processing.

CURRENT PROGRAMS: Improvement of combustion performance and durability and exit temperature distribution of combustors.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: K. Murashima, Manager, Research and Development Department (0425) 56-7241 (Japan).

# HIGH-PRESSURE COMBUSTOR TEST FACILITY



| | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| National Aerospace Laboratory, Japan | **COMPONENT SIZE: (in)** 24 dia x 79 L | **MAX. FLOW RATE: (lb/sec)** 30 | Group A |
| | **DATE BUILT/UPGRADED:** 1977 | **PRESSURE LEVEL: (atm. max.)** 9 | |
| High-Pressure Annular Combustor Test Facility | **REPLACEMENT COST:** $4M | **INLET TEMP. RANGE: (°F)** 730 | |
| | **OPERATIONAL STATUS:** Not operational | **SPEED RANGE: (rpm)** N/A | |
| | | **POWER LEVEL: (hp)** N/A | |
| | Full annular combustor | | |

TESTING CAPABILITIES: This facility originally had the capacity of testing full annular combustors at a maximum pressure level of 15 atm, inlet temperature of 840°F, and flow rate of 55 lb/sec. The operation is currently limited to the values shown above because of the law enforcement of maximum allowable capacity of high-pressure facilities in the institution.

DATA ACQUISITION: Data processing by means of the PDP 11/35 or HP-86 computer.

CURRENT PROGRAMS: None.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Takashi Tamaru, Head of Combustion Laboratory, (0422) 47-5911, ext. 429 (Japan).

| | COMBUSTOR COMPONENT RESEARCH FACILITY | | COMPARABLE FACILITIES |
|---|---|---|---|
| National Aerospace Laboratory, Japan | **COMPONENT SIZE: (in)** 9 dia x 150 L | **MAX. FLOW RATE: (lb/sec)** 8.8 | Group C |
| | **DATE BUILT/UPGRADED:** 1983 | **PRESSURE LEVEL: (atm. max.)** 50 | |
| High-Pressure Combustor Test Facility | **REPLACEMENT COST:** $2M | **INLET TEMP. RANGE: (°F)** Ambient – 850 | |
| | **OPERATIONAL STATUS:** 2 – 3 runs per month | **SPEED RANGE: (rpm)** N/A | |
| | | **POWER LEVEL: (hp)** N/A | |
| | Can-type combustor (3 – 6 inch liner) | | |

TESTING CAPABILITIES: This facility has the capability of testing can-type combustors at a maximum pressure level of 50 atm. The inlet air temperature can be changed independently by a heat exchanger prior to the combustor.

DATA ACQUISITION: Data processing by means of the HP-86 computer.

CURRENT PROGRAMS: Studies of the effect of pressure and combustor design features. Measurements of combustor flame radiation.

PLANNED IMPROVEMENTS: None.

LOCAL INFORMATION CONTACT: Takashi Tamaru, Head of Combustion Laboratory, (0422) 47-5911, ext. 429 (Japan).

# FLIGHT SIMULATION FACILITIES

# FLIGHT SIMULATORS

## INTRODUCTION

The use of flight simulators in lieu of airborne flight operations is widespread in both R&D and pilot training. The R&D flight simulators are typically used in coordinated programs with wind tunnels and flight tests to develop new systems and design concepts for aerospace vehicles. Pilot training simulators, although offering distinct advantages in terms of pilot training efficiency, safety, and cost, are not normally available for R&D work, nor do they generally possess the necessary capabilities. Since the principal objective of this catalogue is to serve the R&D community, the various training facilities used by commercial airlines and the military have been omitted.

Numerous R&D simulation facilities in the United States and abroad, in government laboratories, and in private industry were surveyed. These facilities ranged from small CRT's with a joystick to multimillion dollar research laboratories with powerful motion, visual, and computing capabilities, plus several simulator cockpits (pilot stations). An effort was made to leave out the small or commonplace "facilities" and include only those with significant research capabilities. Of the 85 candidate facilities examined, only 50 have been listed as meeting the above criteria. These are mostly domestic facilities, as indicated in Table Ib, with foreign countries poorly represented because of the lack of available information.

Because the field of Flight Simulation is relatively new compared to wind tunnels and engine test facilities, large R&D Flight Simulation facilities are not as widespread or abundant as the others. This seems to be particularly evident in foreign countries. Also, unlike their sister aeronautical facilities, Flight Simulators are much more evolutionary due to the continually advancing electronics and computational systems on which they so strongly rely. This has created an environment of near term obsolescence in all existing facilities and even in those currently planned or under construction, with the older facilities suffering the most. It is in this context that the following compilation of these facilities and assessment of relative capabilities must be taken. The dynamics of this environment will no doubt alter the picture in the near future.

## COMPARABLE CAPABILITIES

Unlike some aeronautical facilities (e.g., wind tunnels), which can be characterized across several parameters to cover the full spectrum of speed regimes, there is no comparable or consistent methodology for characterizing flight simulation facilities. Although they can be categorized by the makeup of the pilot station, the significance of the facility as a research and development tool is largely determined by its ability to meet requirements for computing power, visual system capability, flight deck displays, motion cues, and air traffic control capability. For these reasons, the flight simulation facilities listed in this catalogue include not only the pilot station or "cockpit," but also the attendant support facilities that

provide the necessary information to the real-time piloted situation. These support facilities include, but are not limited to, dedicated ADP facilities or equipment, visual scene generators, programmable display generators for Heads-up or Heads-down display, and Air Traffic Control (ATC) facilities.

The R&D simulators listed here cover a wide range of R&D work, including:

- Handling qualities evaluation and control system design for proposed and existing aircraft.
- Avionics, Guidance, and Navigation systems development, including controls and displays.
- Weapons systems development.
- Human factors studies, including pilot capabilities and workload.
- Flight management, including aircraft systems, flight procedures, and ATC interactions.

They range from development simulators for specific new aircraft developments to generic flight decks offering significant capability in motion, visual, cockpit displays, or other support facilities.

To permit some comparison of similar capabilities among the various types of simulators, four broad categories were defined and the listed simulators identified and grouped accordingly:

1. Airborne Simulators
2. High-Performance Aircraft Simulators
3. Vehicle-Specific Flight Decks
4. Generic Flight Decks

Although in this breakdown most of the simulators fall into the last two categories, this differentiation still allows for reasonable comparisons and assessment of relative capabilities.

An overall assessment of the information gathered indicates that the United States is the undisputed leader in this category of aeronautical facilities, although some good capabilities exist in the United Kingdom, France, Germany, and Japan, with the latter currently building modern and very capable facilities. The U.S. leadership is generally across the board and resides mostly in the aircraft industry, although NASA owns the premier capability in motion simulators with Ames' Vertical Motion Simulator (VMS) and Flight Simulator for Advanced Aircraft (FSAA).

## AIRBORNE SIMULATORS

Although a number of government, civil, and military installations employ flying test beds to evaluate new developments ranging from avionics to new engines, very few facilities are classified as airborne R&D simulators. The United States has two exceptional facilities that are configured for different types of R&D. These are the Total-In-Flight Simulator (TIFS), operated by CALSPAN for the USAF-WAL, and NASA Langley's Terminal Systems Research Vehicle (TSRV). The latter is designed for aircraft systems R&D work (controls, displays, flight management, ATC procedures, etc.), whereas the TIFS is basically a model-follower with onboard computers, which can be programmed to provide the handling qualities of a range of different aircraft. The best capability in airborne simulators, however, appears to be West Germany's Advanced Technologies Testing Aircraft System (ATTAS), scheduled to be operational in 1986. This facility will combine the capabilities of the TIFS and the TSRV and will be used for handling qualities as well as systems work. Table IV lists the facilities included in this category.

TABLE IV
AIRBORNE SIMULATORS

| Page No. | Facility Name | Location |
|---|---|---|
| 186 | Terminal Systems Research Vehicle (TSRV) | NASA Langley |
| 188 | Total In-Flight Simulator (TIFS) | USAF WAL |
| 187 | NT-33A In-Flight Simulator | USAF WAL |
| 189 | Airborne Flight Simulator | NAE, Canada |
| 191 | Advanced Technologies Testing Aircraft System (ATTAS) | DFVLR, Germany |
| 190 | BO-105 Fly-By-Wire Helicopter Simulator | DFVLR, Germany |

## HIGH-PERFORMANCE AIRCRAFT (AIR-TO-AIR) SIMULATORS

The air-to-air simulators are primarily used for high-performance aircraft with large fields of view. The dome projection techniques allow imagery to cover the pilot's entire field of view (FOV). Most existing facilities use servoed mirrors to project the other moving objects (aircraft, missiles, etc.), and servo-driven transparencies to project a full dome coverage terrain scene. The terrain scenes, however, lack the capability to project translation of the scene for altitude and speed cues. This major shortcoming of the air-to-air simulation facilities has recently been overcome by techniques to project computer-generated imagery (CGI) terrain scenes inside the domes.

McDonnell Aircraft Company in St. Louis, Missouri, has the best overall capability for the air-to-air simulation facilities. In addition to having five domes capable of flying interactively, McDonnell has the most powerful computing facilities (CDC Cyber 170 series computers) and is procuring state-of-the-art capability in CGI terrain scene projection systems. There also are significant capabilities in air-to-air simulators in Germany, France, and England. Table V lists the simulators included in this category.

TABLE V
HIGH-PERFORMANCE AIRCRAFT (AIR-TO-AIR) SIMULATORS

| Page No. | Facility Name | Location |
|---|---|---|
| 192 | Differential Maneuvering Simulator (DMS) | NASA Langley |
| 194 | Manned Air Combat Simulators (MACS) I, II, III, IV, and V | McDonnell Aircraft Co. |
| 193 | LAMARS | USAF WAL |
| 195 | FHI Flight Simulator | Fuji Heavy Industries, Japan |
| – | Air Combat Simulator | France |
| – | Air Combat Simulator | British Aerospace, England |
| – | Dual Flight Simulator | IABG, West Germany |
| – | LASWAVES | Northrop Aircraft |

## VEHICLE-SPECIFIC FLIGHT DECKS

The vehicle-specific flight decks are intended for those R&D simulation facilities working on developments for a specific aircraft flight deck (e.g., a simulator working on developing controls, displays, and flight management functions for a company's next generation commercial transport). The facilities in this category range from the Boeing 737-300 developmental cab, to advanced fighter development cockpits at McDonnell Aircraft and Mitsubishi (Japan), to helicopter simulator facilities at Bell, to the shuttle hardware simulator at Rockwell. Because each facility is designed for specific development work, making comparisons is difficult; however, Boeing probably has the best overall capability with a powerful set of computers, a state-of-the-art CGI system for out-the-window visual scenes, several developmental cabs (one with motion capability), and color cockpit display equipment. McDonnell Aircraft also has excellent facilities for the development of fighter aircraft. The Europeans have excellent facilities in England and France, and the Japanese are building some good new facilities. Table VI lists the simulators included in this category.

TABLE VI
VEHICLE-SPECIFIC FLIGHT DECKS

| Page No. | Facility Name | Location |
|---|---|---|
| 196 | Boeing 727 Flight Simulator | NASA Ames MVSRF |
| 197 | DC-9 Full Workload Simulator | NASA Langley |
| 201 | Hughes Advanced Fighter Simulator | Hughes Aircraft |
| 205 | Shuttle Hardware Simulator | Rockwell |
| 198, 200 | Boeing 747 and 737 | Boeing |
| 199 | Boeing Systems and Workload Cab (B757-767) | Boeing |
| 202, 203, 204 | McDAC FA-18, AV-8B, and GR-MK-V Development Simulation Cabs | McDonnell Aircraft |
| 206 | Flight Simulator for R&D (FSRD) | National Aerospace Labs, Japan |
| 207 | Advanced Technology Fighter (ATF) Flight Simulator | Mitsubishi, Japan |

## GENERIC R&D FLIGHT DECKS

The majority of the R&D simulator facilities fall into this category. Although "generic" in the sense that they are not tied to a specific vehicle configuration, most of these facilities were designed to investigate a specific area of simulation, thereby making across-the-board comparisons difficult. Therefore, these facilities have been compared in the major categories of motion, visual, flight deck, and ATC capability as follows.

### MOTION

In the area of motion capability, NASA Ames has the best overall capability in the Vertical Motion Simulator (VMS), with its 60-ft vertical and 40-ft lateral motion capability. The VMS system includes a family of interchangeable cabs to provide a variety of flight deck configurations, and multiwindow CGI visual scene capability. The addition of the Advanced Cab and Visual System (ACAVS) to the VMS in 1986 will provide dome projection of a state-of-the-art CGI (CT5A), plus highly modular rotorcraft-specific flight deck research capability. Significant motion capability also exists in the USAF's LAMARS Simulator and the RAE's new Advanced Flight Simulator in the United Kingdom.

### VISUAL

The best visual system capability lies with the latest generation CGI systems, which provide good scene resolution and realism, multiple moving objects in the scene, and full-color daylight capability. These new CGI visual scenes are presented to the simulator pilot on projection domes for wide FOV fighter aircraft, on multiple window systems for limited FOV aircraft scenes (transports), and on new partial dome systems for intermediate fields of view. A number of simulation facilities have acquired or are procuring these new CGI systems for essentially comparable visual system capability. The R&D facilities presently owning or acquiring the systems are: NASA Ames for the VMS/ACAVS facility, Boeing's Research Simulation Labs, McDonnell Aircraft's MACS facilities, Northrop's Simulation Labs, the USAF's Human Resources Labs, General Dynamics Simulation Labs, and Hughes Helicopter. The list is growing rapidly.

### FLIGHT DECKS

The best capability for R&D involving the flight deck probably lies in the similar new facilities being developed as a joint project between NASA Langley, NASA Ames, and Lockheed-GA. These new facilities have multiple CRT displays on the panel with programmable display generators that allow R&D on the displays. The facilities also have capability for R&D on the use of touchpanels, voice control and warnings, pilot control and display units (CDU), and other flight management and human factors functions. Other facilities with significant flight deck R&D capabilities include Boeing and Grumman in the United States and the Airbus facilities in France.

TABLE VII
GENERIC FLIGHT DECKS

| Page No. | Facility Name | Location |
|---|---|---|
| 209 | Flight Simulator for Advanced Aircraft (FSAA) | NASA ARC |
| 210, 211 | Vertical Motion Simulator (VMS) | NASA ARC |
| 208, 227 | Advanced Concepts Flight Simulator (ACFS) | Lockheed-GA & NASA ARC |
| 214 | Advanced Concepts Simulator | NASA LaRC |
| 212 | Visual Motion Simulator | NASA LaRC |
| 213 | Mission Oriented Terminal Area Simulator (MOTAS) | NASA LaRC |
| – | Multicrew Simulator | USAF FDL-WPAFB |
| 216 | Fighter/Bomber Simulator | USAR FDL-WPAFB |
| 221 | Engineering Interactive Simulator | Bell |
| 222 | Multipurpose Cab | Boeing, Seattle |
| 223 | Engineering Flight Simulator | Boeing Vertol |
| 224, 225, 226 | Large Amplitude Research (LARS), Crew Station Technology Lab, and Six DOF Simulators | Grumman |
| 227 | Man-Vehicle Systems Lab. (or ACFS) | Lockheed-GA |
| 228, 229 | Large Amplitude (LAS), and Visual Flight Simulators (VFS) | Northrop |
| 231 | Engineering Development Simulator | Sikorsky |
| 232 | Air Traffic Management and Operations Simulator (ATMOS) | DFVLR, Germany |
| 233 | Simulator for Aircraft R&D (SARD) | Kawasaki, Japan |
| 234 | Moving Base Flight Simulator (MBFS) | Netherlands |
| – | Advanced Flight Simulator | RAE/Bedford, U.K. |

# CROSS-INDEX OF FLIGHT SIMULATION FACILITIES BY INSTALLATION

## AIRBORNE SIMULATORS

| Page Number | Location and Facility Description | Simulation | Motion DOF | Visual | Comments |
|---|---|---|---|---|---|
| | **NASA** | | | | |
| | Langley Research Center | | | | |
| 186 | Terminal System Research Vehicle Simulator | Advanced Controls, Displays, Flight Management Systems | Full Fixed Base | All/Model; Board | 1 Simulator in Aircraft; Identical Ground Based Simulator |
| | **DOD** | | | | |
| | Wright Patterson Flight Dynamics Lab | | | | |
| 187 | NT-33A In-Flight Simulator | X-15, X-24, A-9, A-10 F-15, F-16, ATFI/F-16, F-18 | 3 moments only | Real World Vision | Model Follower Aircraft |
| 188 | NC-131H Total Inflight Simulator | B-1 Concorde SSt, YOM-98, Shuttle, X-29 | 6 | Real World Vision | Model Follower Aircraft |
| | **CANADA** | | | | |
| | NAE Flight Research Laboratory | | | | |
| 189 | Airborne Flight Simulator | Rotorcraft and VSTOL Aircraft | 4 | N/A | |
| | **GERMANY** | | | | |
| | DFVLR | | | | |
| 190 | Flying Simulator Helicopter Bo 105 S-3 | High-Maneuverable Light Twin-engine | Full | Actual Flight (Real World) | Model Follower |
| 191 | Flying Simulator VFW 614 G-17 ATTAS | Advanced 2 Engine Jet | Full/Fixed Base | Actual Flight (Real World) | Experimental Cockpit for Ground Base of Flight |

HIGH PERFORMANCE AIRCRAFT SIMULATORS

| Page Number | Location and Facility Description | Simulation | Motion DOF | Visual | Comments |
|---|---|---|---|---|---|
| | NASA | | | | |
| | Langley Research Center | | | | |
| 192 | Differential Maneuvering Simulator | High Performance Aircraft and Helicopters | 1 (buffet only) | Sky-Earth Transparencies Scale Model Targets | Dual Projection Domes for ACM |
| | DOD | | | | |
| | Wright Patterson Flight Dynamics Lab | | | | |
| 193 | Large Amplitude Multimode Aerospace Research Simulator (LAMARS) | A-10, F-15, F-16, F-106, AFTI/F-16, X-29 | 5 | Day, Dusk, Night Solid Model Terrain TV Projector | Projection Dome with Motion |
| | INDUSTRY | | | | |
| | McDonnell Aircraft Co | | | | |
| 194 | Manned Air Combat Simulator #1, #2, #3, #4, #5 | F-15, FA-18 | Fixed Base | Day, Dusk, Color Multiple-Model Point Light Terrain Map or Flying Spot Scanner | Multiple Projection Domes for ACM |
| | JAPAN | | | | |
| | Fuji Heavy Industries | | | | |
| 195 | Flight Simulator | All Types of Fighter Aircraft and VSTOL Transport | Fixed Base | Sky-Earth Transparencies Scale Model targets | Single Projection Dome |

## VEHICLE-SPECIFIC SIMULATORS

| Page Number | Location and Facility Description | Simulation | Motion DOF | Visual | Comments |
|---|---|---|---|---|---|
| | **NASA** | | | | |
| | Ames Research Center | | | | |
| 196 | Boeing 727 Flight Simulator | Boeing 727 | 6 | Link & Miles Image II | Part of MVSRF |
| | Langley Research Center | | | | |
| 197 | DC-9 Full Workload Simulator | Complete DC-9 with CDTI Display | Fixed Base | Model Board | Full Workload Cab |
| | **INDUSTRY** | | | | |
| | The Boeing Company | | | | |
| 198 | 737-300 Engineering Cab | 737-300 | Fixed | CGI with Multiple Windows | |
| 199 | Systems and Workload Cab | 757, 767 | – | CGI with Multiple Windows | |
| 200 | Flight Systems Laboratory | 747 | – | None | |
| | Hughes Aircraft Company | | | | |
| 201 | Advanced Fighter Simulator | F/A-18, F-14 Rear Seater | Fixed Base | None | Heads Up and Heads Down Displays |

## VEHICLE SPECIFIC SIMULATORS

| Page Number | Location and Facility Description | Simulation | Motion DOF | Visual | Comments |
|---|---|---|---|---|---|
| | INDUSTRY | | | | |
| | McDonnell Aircraft Company | | | | |
| 202 | F/A-18 Developmental Simulator (MACS 3.5) | F/A-18 | Fixed Base | CGI with Multiple Windows | |
| 203 | Manned Simulator VSTOL #1 (MSV-1) | AV-8B | Fixed Base | CGI with Multiple Windows | |
| 204 | Manned Simulator VSTOL #2 | GRMK-V | Fixed | CGI with Multiple Windows | |
| | Rockwell International | | | | |
| 205 | Space Shuttle Hardware and Software Evaluators | Shuttle | Fixed Base | CBS Color Camera, Ferrand Optical Probe | |
| | JAPAN | | | | |
| | NAL | | | | |
| 206 | Flight Simulator for Research & Development | Medium to Large Transports | 6 | CGI with Multiple Windows | |
| | Fuji Heavy Industries | | | | |
| 207 | Flight Simulator | Advanced Technology Fighters | Fixed Base | CGI with Multiple Windows | |

## GENERIC FLIGHT DECKS

| Page Number | Location and Facility Description | Simulation | Motion DOF | Visual | Comments |
|---|---|---|---|---|---|
| | <u>NASA</u> | | | | |
| | Ames Research Center | | | | |
| 208 | Advanced Concepts Flight Simulator | Advanced Aircraft LN 1995 | – | Link & Miles Image II | Part of MVSRF |
| 209 | Flight Simulator for Advanced Aircraft (FSAA) | OSRA, RSRS, F111, Shuttle, KG135 UH60, UH-1H, XV15 | 6 | Model Board/Calligraphic TV Camera | 100 ft Lateral Motion |
| 210 | Vertical Motion Simulator (VMS) | Shuttle, XV15, UH60, | 6 | CGI, Full Color and Calligraphic | 60 ft Vertical 40 ft Lateral Motion |
| 211 | 6 Degrees of Freedom | – | 6 | TV Camera, Model Board | |
| | Langley Research Center | | | | |
| 212 | Visual Motion Simulator | Variety of Aircraft | 6 | Model Board | |
| 213 | Mission Oriented Terminal Area Simulation (MOTAS) | Variety of Aircraft | – | ATC controller scopes | Air-traffic Control Simulator |
| 214 | Advanced Concepts Simulator | Advanced, all electric twin engine transport | Fixed Base | None | "All glass" Cockpit with Touch Panels and Voice I/O |
| | Johnson Space Center | | | | |
| 215 | Systems Engineering Simulator | Space Shuttle | – | E & S CT3 | |

GENERIC FLIGHT DECKS

| Page Number | Location and Facility Description | Simulation | Motion DOF | Visual | Comments |
|---|---|---|---|---|---|
| | <u>DOD</u> | | | | |
| | Wright Patterson Flight Dynamics Lab | | | | |
| 216 | Flight/Bomber Simulator | F-16 | 5 | All, Solid Model Terrain Board | |
| | Williams Air Force Base | | | | |
| 217 | Fiber-Optic Helment Mounted Display (FOHMD) | F-16C<br>AT-38 | Fixed | CGI | |
| 218 | 24' Diam Limited Field of View Dome | F-16A with Block 10 and 15 Configurations | Fixed | CGI | |
| 219 | 24" Diam Full Field of View Dome | F-16C | Fixed | CGI | |
| 220 | Low Altitude Night Terrain (Infrared) Navigation | F-16C | Fixed | CGI | |
| | <u>INDUSTRY</u> | | | | |
| | Bell Helicopter | | | | |
| 221 | Engineering Interactive | XV15, JVX, LHX<br>AH1, UH1, M222 | Fixed Base | CGI | |
| | The Boeing Company | | | | |
| 222 | Multipurpose Cab | 707, 727, 737, 747 | 3 | CGI with Multiple Windows | |

## GENERIC FLIGHT DECKS

| Page Number | Location and Facility Description | Simulation | Motion DOF | Visual | Comments |
|---|---|---|---|---|---|
| | INDUSTRY | | | | |
| | Boeing Vertol | | | | |
| 223 | Engineering Flight Simulator Facility | Tandem Rotor, Tilt Rotor, Single Rotor | 6 | CGI with Multiple Windows | |
| | Grumman Aerospace | | | | |
| 224 | Six Degrees of Freedom Moving Base Simulator | X-29A, F-14, A-6 | 6 | Model Board, Optical Probe, Color TV, Moving Target Model | Window or spherical screen |
| 225 | Crew Station Technology Lab | F-14, A-6, VSTOL | Fixed Base | Model Board | Partial Dome Projection |
| 226 | Large Amplitude Research Simulator (LARS) | VTOL | 6 | None | |
| | Lockheed-Georgia Co | | | | |
| 227 | Man-Vehicle Systems Laboratory | Advanced Concepts Transport, Assault Transport, C-130, C-5 | 6 | Model Board, CGI with Multiple Windows | |
| | Northrop | | | | |
| 228 | Large Amplitude Simulator (LAS) | Tactical Aircraft | 5 | Sky-Earth Transparencies Scale Model Targets | |
| 229 | Visual Flight Simulator (VFS) | Tactical Aircraft | None | Sky-Earth Transparencies Scale Model Targets | |

## GENERIC FLIGHT DECKS

| Page Number | Location and Facility Description | Simulation | Motion DOF | Visual | Comments |
|---|---|---|---|---|---|
| | INDUSTRY | | | | |
| | Sikorsky Aircraft | | | | |
| 230 | Fixed Base Simulator | Rotorcraft | Fixed Base | CGI | |
| 231 | Engineering Development Simulator | Rotorcraft | 6 | CGI | |
| | GERMANY | | | | |
| | DFVLR | | | | |
| 232 | Air Traffic Management and Operations Simulator (ATMOS) | Advanced FBW Transport | – | ATC Controller Scopes | Air Traffic Control Simulator |
| | JAPAN | | | | |
| | Kawasaki Heavy Industries | | | | |
| 233 | Simulator for Aircraft Research & Development (SARD) | Advanced Fighter & Trainer Aircraft | Fixed | CGI with Multiple Windows | |
| | NETHERLANDS | | | | |
| | NRL | | | | |
| 234 | Moving Based Flight Simulator | Civil and Military Single/Twin Engine Aircraft | 4 | Model Board | |

| | | | |
|---|---|---|---|
| 2 | 1 | | COMPARABLE FACILITIES |
| | DATE BUILT/UPGRADED: 4<br>REPLACEMENT COST: 5<br>OPERATIONAL STATUS: 6 | MOTION: 8<br>Degrees of Freedom:<br>Linear Displacement:<br>g's: | 11 |
| 3 | SYSTEMS SIMULATED: 7<br>Aircraft Type(s):<br>No. of Crew Stations:<br>ATC:<br>Other: | VISUAL: 9<br>Field of View:<br>Image Generation:<br>Image Presentation: | |
| | | HOST COMPUTER SYSTEM: 10 | |

TYPICAL PROGRAMS: A listing of the research activities typically conducted in the facility.

PLANNED IMPROVEMENTS: Equipment or facility upgrades contemplated for the near future.

CONSTRAINTS: Inherent limitations of the facility.

LOCAL INFORMATION CONTACT: Lists the name, title, address, and phone number of the person to contact for additional information on the facility.

# EXPLANATION OF FLIGHT SIMULATORS DATA SHEETS

As in the case of the Airbreathing Propulsion Facilities, the box at the top of these data sheets is designed to provide a quick-glance digest of a simulator's most pertinent characteristics. It contains both technical and operational data. Individual descriptions corresponding to the numbered boxes on the opposite page are given below. The supplementary information beneath the box is tailored to the flight simulation facilities, and is somewhat different from the wind tunnel and airbreathing propulsion facilities versions. An explanation of this information is given on the opposite page.

1. *Type of Simulator*: Airborne, High Performance Aircraft, Vehicle Specific, Generic.

2. Name of the installation where the facility is located, owner, city and state, or country (when foreign).

3. Proper or generic name of the facility, with additional qualifiers or identifiers as appropriate.

4. *Date Built/Upgraded*: Self-explanatory.

5. *Replacement Cost*: Best estimate of the current value (1985) of the facility. Cost in millions of dollars ($M).

6. *Operational Status*: An indication of a facility's current work load or availability.

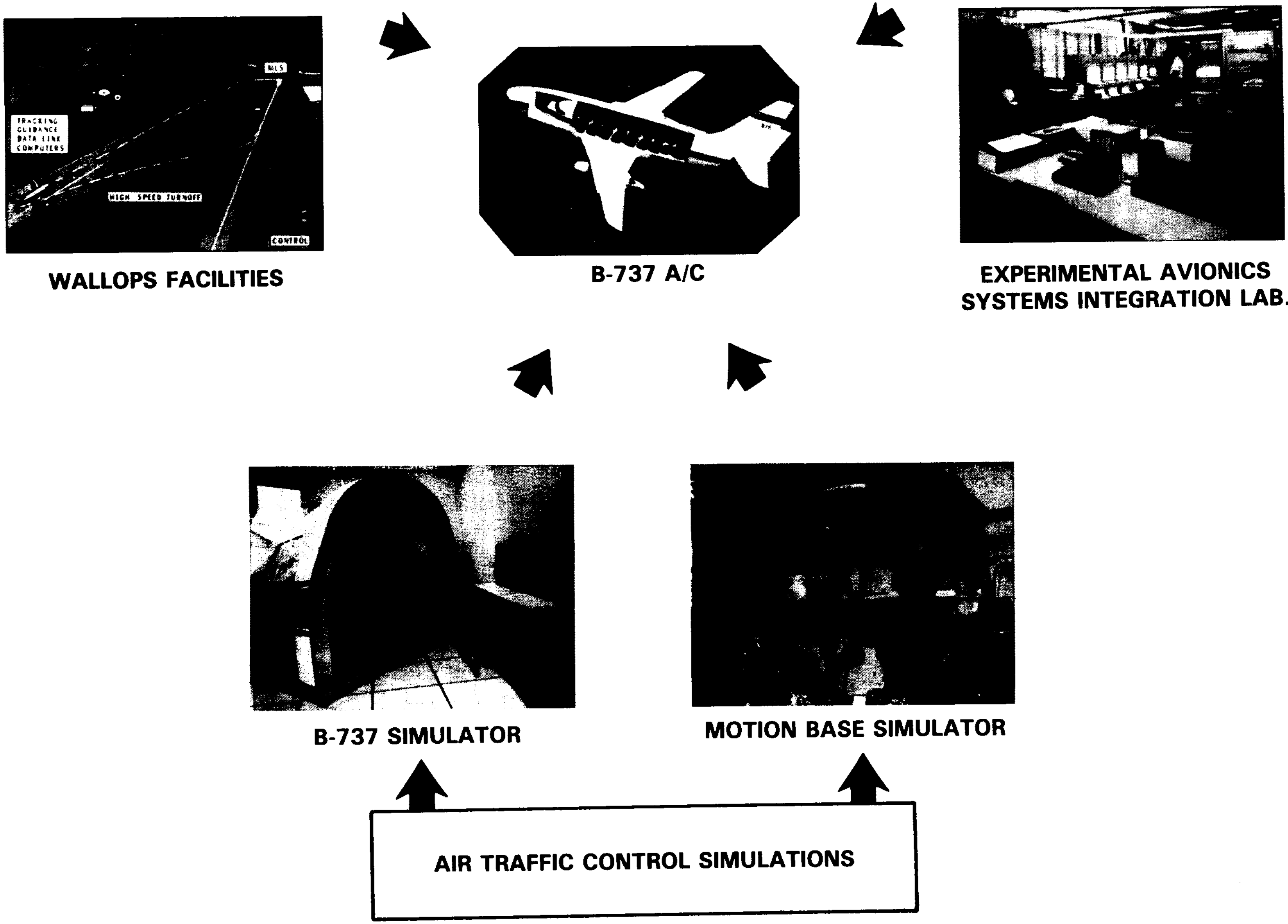
7. *Systems Simulated*: An indication of the aircraft types simulated plus other pertinent "cockpit" information.

8. *Motion*: An indication of whether the simulator has motion or is fixed base. If motion, the appropriate characteristics are given.

9. *Visual*: As the single, most crucial element of a flight simulator, an attempt is made to capture the most salient visual characteristics, such as: type of image projection, whether color, day/night simulation, field of view provided, plus information on the type of equipment used.

10. *Host Computer System*: An indication of a simulator's overall capacity and currency, by highlighting its main-frame computer and related equipment.

11. *Comparable Facilities*: Other flight simulators or facilities with similar characteristics and which may be used as alternatives.


TRACKING
GUIDANCE
DATA LINK
COMPUTERS
MLS
HIGH SPEED TURNOFF
CONTROL
WALLOPS FACILITIES
B-737 A/C
EXPERIMENTAL AVIONICS
SYSTEMS INTEGRATION LAB.
B-737 SIMULATOR
MOTION BASE SIMULATOR
AIR TRAFFIC CONTROL SIMULATIONS

| NASA–Langley Research Center | AIRBORNE SIMULATORS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1973/1984<br>**REPLACEMENT COST:** $36M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Ground-based system is fixed-base; Aircraft has unlimited motion.<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | GR–DFVLR:<br>Advanced Technologies Testing Aircraft System |
| Transport System Research Vehicle Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Advanced Controls, Displays, and Flight Management Systems B-737<br>**No. of Crew Stations:** 2 (one ground based, one on aircraft)<br>**ATC:** Both crew stations can fly with live or simulated traffic.<br>**Other:** Selectable low-level wind shears for ground-based systems | **VISUAL:** Day, Dusk, Night, Color<br>**Field of View:** 60° diagonal<br>**Image Generation:** Redifussion Model/Board<br>**Image Presentation:**<br>Manufacturer: Redifussion<br>Type: Collimated Mirror-Beam Splitter<br>**HOST COMPUTER SYSTEM:** Cyber 175 for ground-based crew station; two Norden PDP 11/70's for aircraft | |

TYPICAL R&D PROGRAMS:

- Terminal area traffic
- Control/displays
- Flight management studies

PLANNED IMPROVEMENTS: Six multicolor displays for both crew stations by late 1985.

CONSTRAINTS: None.

LOCAL INFORMATION CONTACT: J. R. Hall, NASA–Langley Research Center, Mail Stop 265, Hampton, VA 23665, (804) 865-2435.

<table>
<tr><td rowspan="4">DOD–Flight Dynamics Laboratory, Wright-Patterson Air Force Base, OH</td><td colspan="2">AIRBORNE SIMULATORS</td><td>COMPARABLE FACILITIES</td></tr>
<tr><td>DATE BUILT/UPGRADED: 1957/1978</td><td rowspan="3">MOTION: Airborne Simulator<br>Degrees of Freedom: 3 (moments only)<br>Linear Displacement:<br>g's: ±5, -1 vert, ±0.25 lat</td><td rowspan="3">GR–DFVLR:<br>Advanced Technologies Aircraft System</td></tr>
<tr><td>REPLACEMENT COST: $35M</td></tr>
<tr><td>OPERATIONAL STATUS: Operational</td></tr>
<tr><td rowspan="2">NT-33A<br>In-Flight<br>Simulator</td><td rowspan="2">SYSTEMS SIMULATED:<br>Aircraft Type(s): X-15, X-24, A-9, A-10, F-15, F-16, ATFI/F-16, F-18<br>No. of Crew Stations: 2<br>1 safety pilot<br>1 evaluation pilot<br>ATC: Yes. Actual ATC in local area.<br>Other: Reconfigurable instrument panel, controls, programmable, heads-up display</td><td colspan="2">VISUAL: Real World Visual<br>Field of View: N/A<br>Image Generation: N/A<br>Image Presentation: N/A</td></tr>
<tr><td colspan="2">HOST COMPUTER SYSTEM: Rolm 1602 Digital Computer with 32K memory for HUD and variable stability system, custom-built analog computers for variable stability and feel systems, 28-channel digital or 14-channel FM recorder</td></tr>
</table>

TYPICAL R&D PROGRAMS:

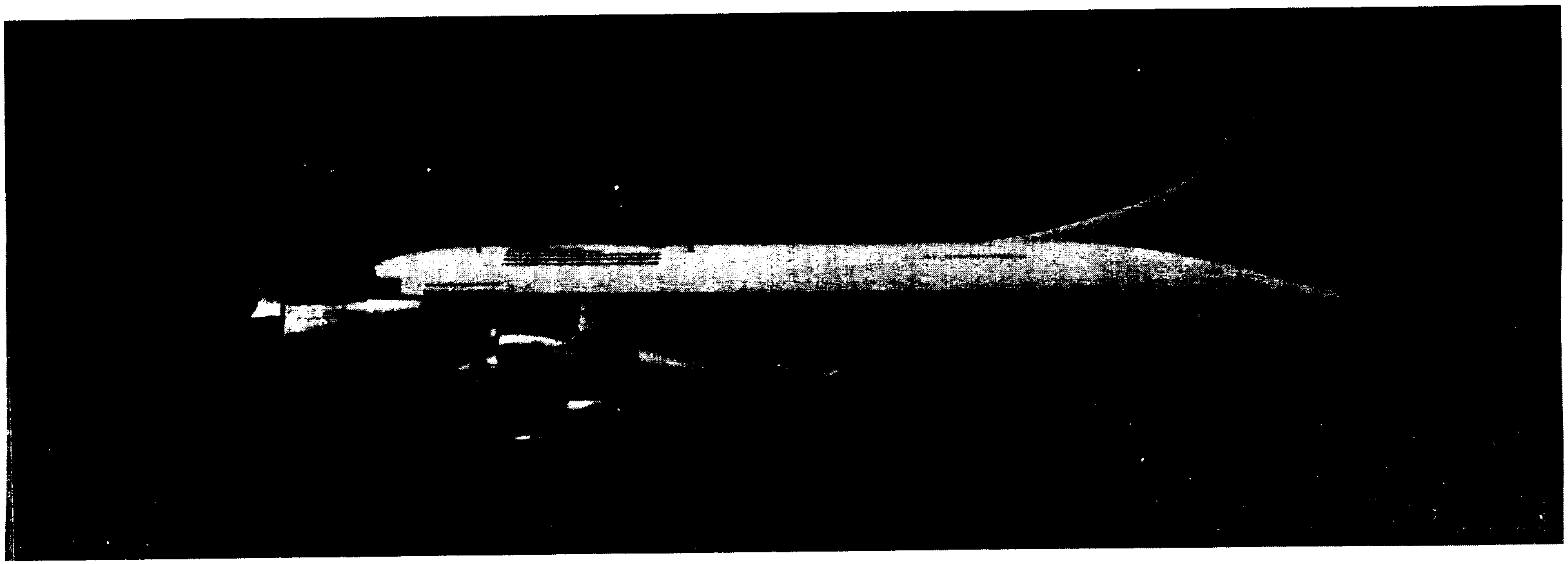
- Flight control development
- Pre-first-flight simulation
- Handling qualities investigations
- Handling qualities specification development

PLANNED IMPROVEMENTS:

- New computers
- New heads-up display unit
- Ground simulator capability
- All attitude INS
- Serial bit stream digital recorder

CONSTRAINTS: Speed, altitude, + g capabilities are significantly less than current and future fighter/attack aircraft.

LOCAL INFORMATION CONTACT: Steven R. Markman, AFWAL/FIGD, Wright-Patterson Air Force Base, OH 45433, (513) 255-3853.



| DOD–Flight Dynamics Laboratory, Wright-Patterson Air Force Base, OH | AIRBORNE FLIGHT SIMULATORS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1970/1980<br>**REPLACEMENT COST:** $30M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Airborne Simulator<br>**Degrees of Freedom:** 6<br>**Linear Displacement:** N/A<br>**g's:** 0.2 to +2 up to 1/2 | DFVLR–Germany: Advanced Technologies Testing Aircraft System |
| NC–131H Total Inflight Simulator<br><br>(TIFS) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** B-1, Concorde SST, YOM-98, Space Shuttle, X-29<br>**No of Crew Stations:** 4<br>2 safety pilots<br>2 evaluation pilots<br>**ATC:** Yes. Actual ATC in local area.<br>**Other:** Reconfiguration cockpit, controls, displays | **VISUAL:** Real World Visual<br>**Field of View:** N/A<br>**Image Generation:** N/A<br>**Image Presentation:** N/A<br><br>**HOST COMPUTER SYSTEM:** 2 RV77-400 Digital Computers with 32K memory each for aircraft model; 2 custom-built Analog Computers with total of 1400 amplifiers for model and model following; 58-channel down link; 4-channel strip chart (selectable from 40 input channels) | |

TYPICAL PROGRAMS:

- Flight control development
- Pre-first-flight simulation
- Human factors studies
- Handling qualities investigations
- Handling qualities specification development
- Motion studies

PLANNED IMPROVEMENTS:

- New digital computers
- New model following algorithms
- New elevator torque tube (improved pitch response)
- Weight reduction
- Serial bit digital recorder

CONSTRAINTS: Speed, altitude, + g capabilities limited to less than that of baseline C-131.

LOCAL INFORMATION CONTACT: Steven R. Markman, AFWAL/FIGD, Wright-Patterson Air Force Base, OH 45433, (513) 255-3853.

| Canada–NAE Flight Research Laboratory, Ottawa, Canada | AIRBORNE SIMULATORS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1969<br>**REPLACEMENT COST:** $3M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Airborne<br>**Degrees of Freedom:** 4<br>**Linear Displacement:**<br>**g's:** | GR–DFVLR:<br>Bo 105 Helicopter |
| Airborne*<br>Flight Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>Rotorcraft and V/STOL aircraft<br>**No. of Crew Stations:** 2<br>**ATC:**<br>**Other:** | **VISUAL:**<br>**Field of View:**<br>**Image Generation:** N/A<br>**Image Presentation:**<br>**HOST COMPUTER SYSTEM:** Three PDP-11 microcomputers (LSI-11), three special-purpose analog computers | |

TYPICAL R&D PROGRAMS:

- Helicopter and V/STOL aircraft handling qualities studies
- Investigations of advanced control systems
- Pilot workload and pilot/aircraft interface studies
- Investigations of advanced display systems and concepts

PLANNED IMPROVEMENTS: Continuously evolving.

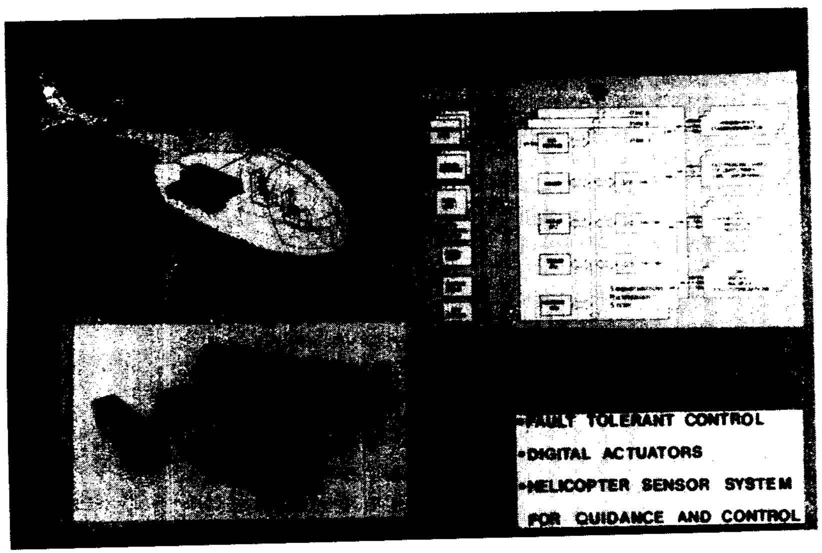
CONSTRAINTS: Performance and maneuvering envelope of Bell 205A-1 helicopter.

LOCAL INFORMATION CONTACT: M. Morgan, Flight Research Laboratory, National Research Council, Montreal Road, Ottawa, K1A OR6, Canada.

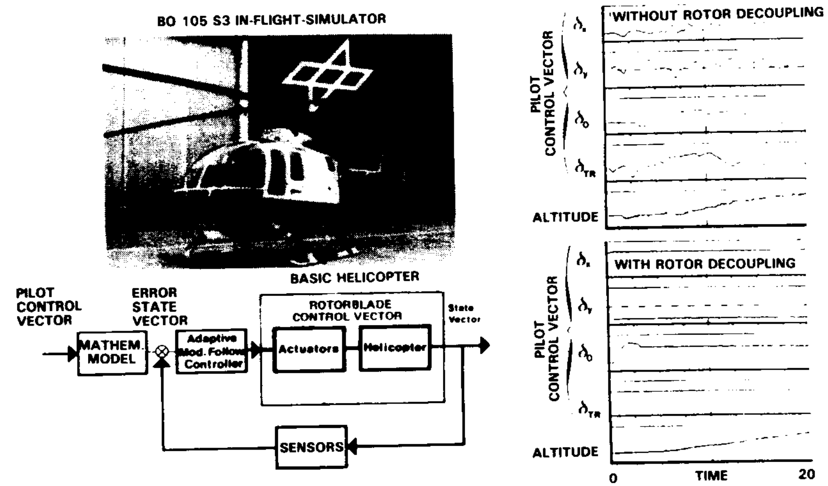
*Variable stability and control Bell 205A-1; full authority fly-by-wire station.

FLY-BY-WIRE-HELICOPTER

**FLY-BY-WIRE-HELICOPTER**




**DYNAMIC CLIMB**
**EFFECT OF ROTOR DECOUPLING**



| Germany–DFVLR | AIRBORNE SIMULATORS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1974<br>**REPLACEMENT COST:**<br>**OPERATIONAL STATUS:** 1985/1986 | **MOTION:**<br>**Degrees of Freedom:**<br>**Linear Displacement:** Flying-simulator within envelope to the standard Bo 105<br>**g's:** | Canada–NAE Flight Research Lab:<br>Airborne Flight Simulator |
| Flying-Simulator Helicopter Bo 105 S-3 | **SYSTEMS SIMULATED:** High-maneuverable light twin-engine<br>**Aircraft Type(s):**<br>Helicopters<br>**No.of Crew Stations:** 1 evaluation pilot<br>**ATC:** Actual<br>**Other:** | **VISUAL:** Actual flight<br>**Field of View:**<br>**Image Generation:**<br>**Image Presentation:**<br>**HOST COMPUTER SYSTEM:**<br>LSI 11 | |

TYPICAL R&D PROGRAMS:

PLANNED IMPROVEMENTS:

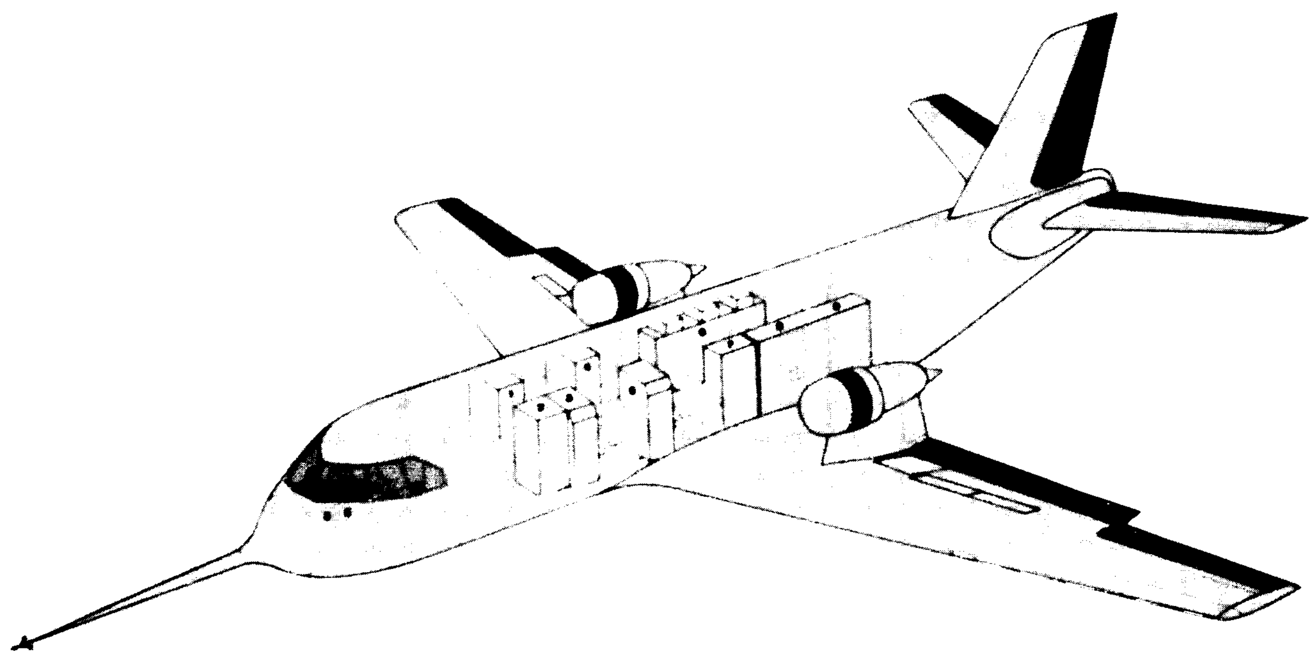
CONSTRAINTS:

LOCAL INFORMATION CONTACT:

# FLYING SIMULATOR

## ADVANCED TECHNOLOGIES TESTING AIRCRAFT SYSTEM

## ATTAS



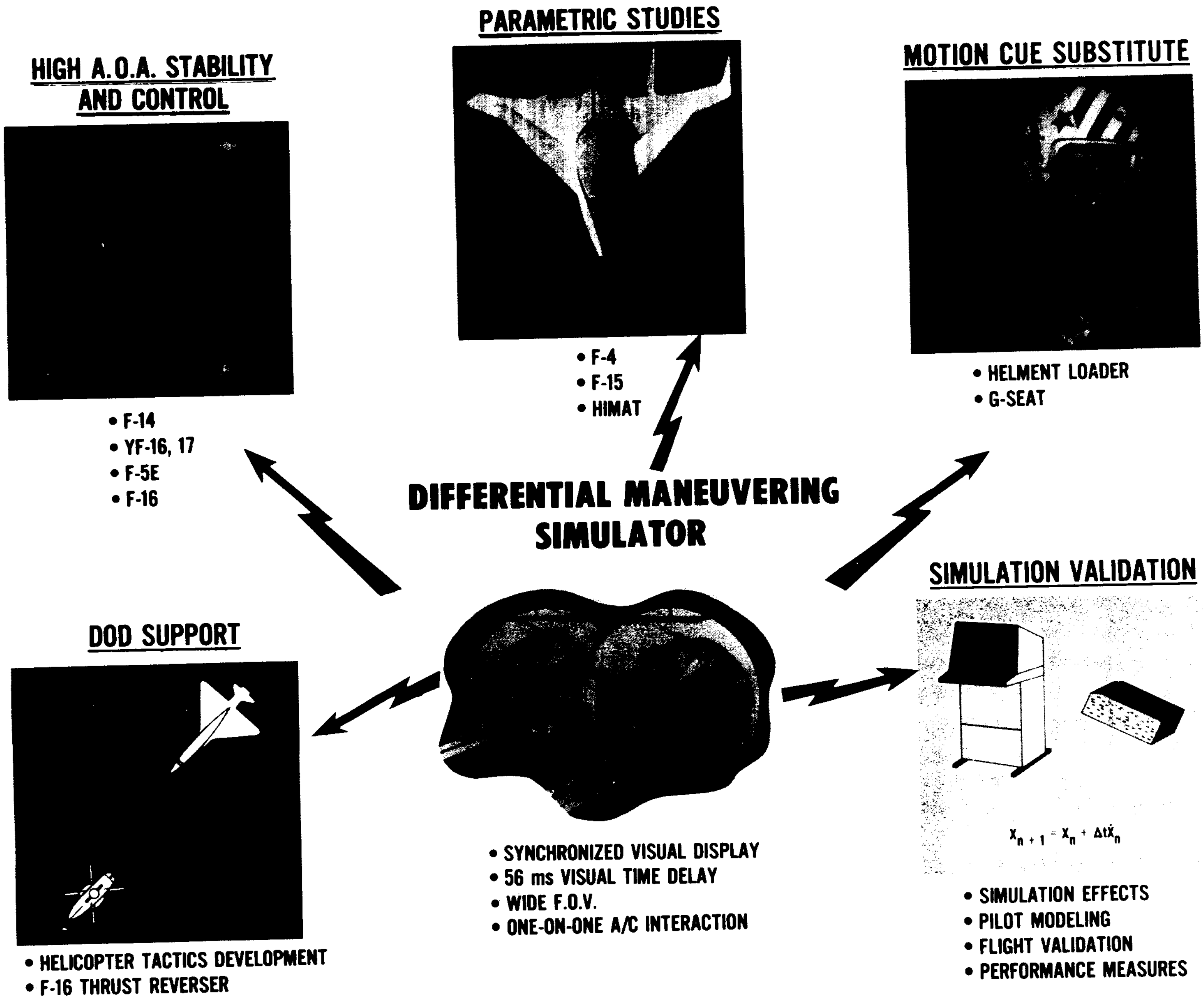
<table>
<tr><td rowspan="3">Germany–DFVLR</td><td colspan="2">AIRBORNE SIMULATORS</td><td>COMPARABLE FACILITIES</td></tr>
<tr><td>DATE BUILT/UPGRADED: 1985/1986</td><td rowspan="2">MOTION: Actual flight<br>Degrees of Freedom: 6<br>Linear Displacement: N/A<br><br>g's:</td><td rowspan="2">NASA–LaRC:<br>Transport Systems<br>Research<br>Simulator</td></tr>
<tr><td>REPLACEMENT COST:<br><br>OPERATIONAL STATUS: Operational 1986</td></tr>
<tr><td rowspan="2">Flying-Simulator<br>VFW 614<br>G-17<br>ATTAS</td><td rowspan="2">SYSTEMS SIMULATED:<br>Aircraft Type(s):<br>Advanced twin-engine transport<br><br>No. of Crew Stations: 1<br>(evaluation pilot)<br><br>ATC: Yes<br><br>Other: Experimental cockpit in cabin area</td><td colspan="2">VISUAL: Actual flight<br>Field of View:<br><br>Image Generation:<br><br>Image Presentation:</td></tr>
<tr><td colspan="2">HOST COMPUTER SYSTEM:<br>ROLM MSE 14, Eclipse, and ROLM HAWK</td></tr>
</table>

TYPICAL R&D PROGRAMS:

PLANNED IMPROVEMENTS:

CONSTRAINTS:

LOCAL INFORMATION CONTACT:



HIGH A.O.A. STABILITY AND CONTROL
• F-14
• YF-16, 17
• F-5E
• F-16
PARAMETRIC STUDIES
• F-4
• F-15
• HIMAT
MOTION CUE SUBSTITUTE
• HELMENT LOADER
• G-SEAT
DIFFERENTIAL MANEUVERING SIMULATOR
• SYNCHRONIZED VISUAL DISPLAY
• 56 ms VISUAL TIME DELAY
• WIDE F.O.V.
• ONE-ON-ONE A/C INTERACTION
DOD SUPPORT
• HELICOPTER TACTICS DEVELOPMENT
• F-16 THRUST REVERSER
SIMULATION VALIDATION
$X_{n+1} = X_n + \Delta t\dot{X}_n$
• SIMULATION EFFECTS
• PILOT MODELING
• FLIGHT VALIDATION
• PERFORMANCE MEASURES

| | | | |
|---|---|---|---|
| NASA–Langley Research Center, Hampton, VA | **HIGH PERFORMANCE AIRCRAFT** | | **COMPARABLE FACILITIES** |
| | **DATE BUILT/UPGRADED:** 1971/1976<br>**REPLACEMENT COST:** $8M<br>**OPERATIONAL STATUS:** Operational | **MOTION:**<br>**Degrees of Freedom:** 1 (buffet only)<br>**Linear Displacement:** ±2 in, vertical only<br>**g's:** ±3 | McDonnell Aircraft Co.:<br>Manned Air Combat Simulators (MACS) |
| Differential Maneuvering Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>A large number of high performance aircraft and helicopters<br>**No of Crew Stations:**<br>2 (interactive)<br>**ATC:** Yes<br>**Other:** Weapons, G-suits, G-seats, helmet loaders | **VISUAL:**<br>**Field of View:** 300°H, ±90°V<br>**Image Generation:** Northrop: Sky-Earth transparencies and scale model targets<br>**Image Presentation:** Manufacturer: Northrop<br>Type: Dome projection with servoed mirrors for target aircraft<br>**HOST COMPUTER SYSTEM:**<br>CDC Cyber 175 with Adage graphics systems for head-up and head-down displays | |

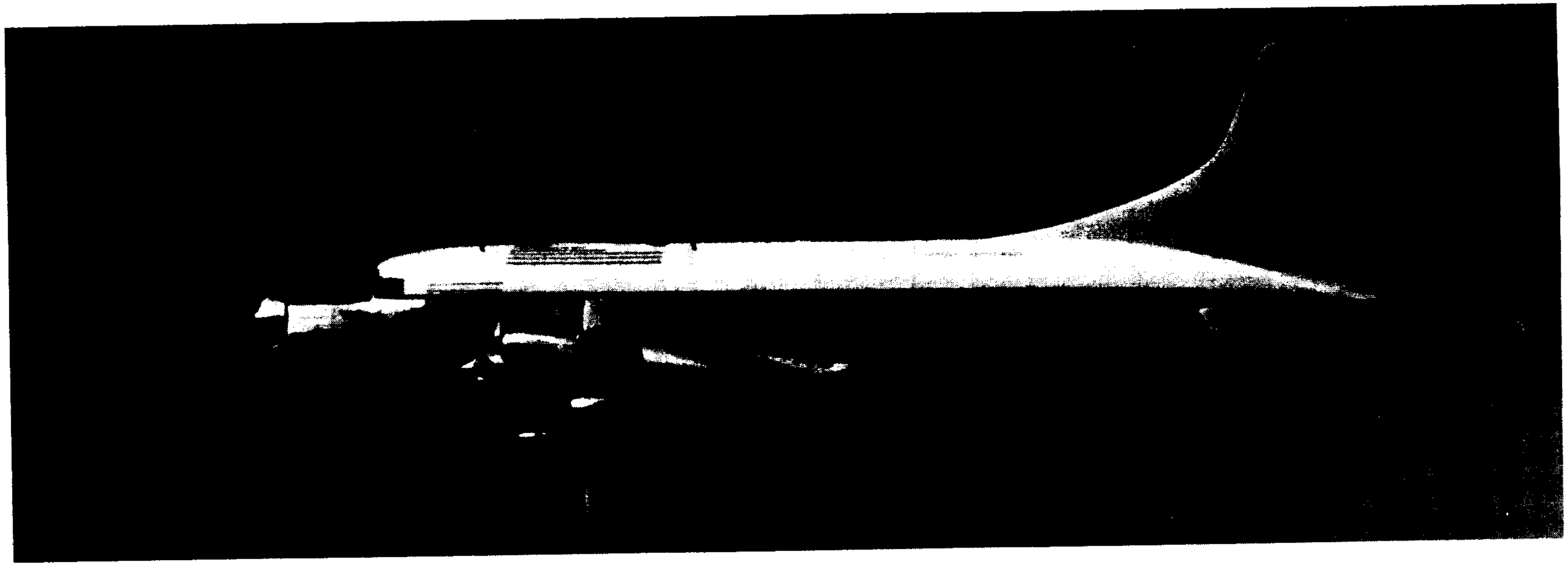
TYPICAL R&D PROGRAMS:

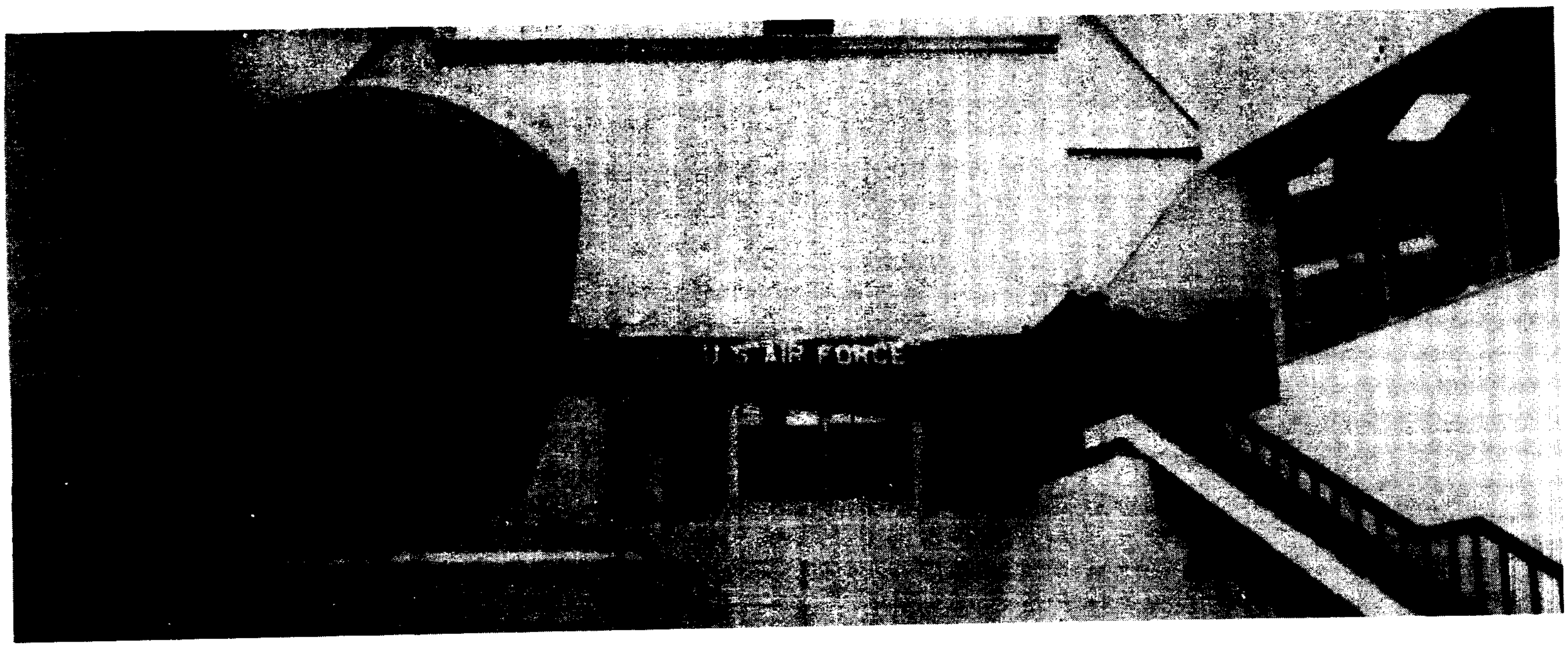
- High performance aircraft handling qualities research
- High angle-of-attack control system design for fighters
- Aircraft/rotorcraft air-to-air maneuverability

PLANNED IMPROVEMENTS: CGI terrain projection for translational cues.

CONSTRAINTS: No translation of terrain scene.

LOCAL INFORMATION CONTACT: B. R. Ashworth, NASA–Langley Research Center, Hampton, VA 23665, (804) 865-3874.




U S AIR FORCE

| DOD–Flight Dynamics Laboratory, Wright-Patterson Air Force Base, OH | HIGH PERFORMANCE AIRCRAFT | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1975<br>**REPLACEMENT COST:** $6M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Moving<br>**Degrees of Freedom:** 5 (no long.)<br>**Linear Displacement:** (ft)<br>Vert: ±10; lat: ±10<br>**g's:** ±3 vert, ±1.65 lat | Northrop: Large Amplitude Simulator |
| Large Amplitude Multimode Aerospace Research Simulator (LAMARS) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** A-10, F-15, F-16, F-106, AFTI/F-16, X-29<br>**No. of Crew Stations:** 1<br>**ATC:** N/A<br>**Other:** Heads-up display, sound simulator, target aircraft, McFadden control loader | **VISUAL:** Day, Dusk, Night<br>**Field of View:** 266° peripheral, 48° terrain<br>**Image Generation:** Rediffusion: Solid Model Terrain Board<br>**Image Presentation:**<br>Manufacturer: Northrop<br>Type: TV Projector<br>**HOST COMPUTER SYSTEM:** Two SEL 32/77 digital computers with 256 KW of memory each; two EAI Pacer 100 digital computers; two CSPI MAP 300 array processors; one EAI Model 327 Hyshare Interface; two EAI 781 analog computers; one EAI 7800 analog computer | |

TYPICAL R&D PROGRAMS (generally used for fighter/attack class aircraft):

- Control system development and evaluation
- Pre-first-flight verification and familiarization
- Flying qualities research
- Accident investigation
- Fire control/navigation system development

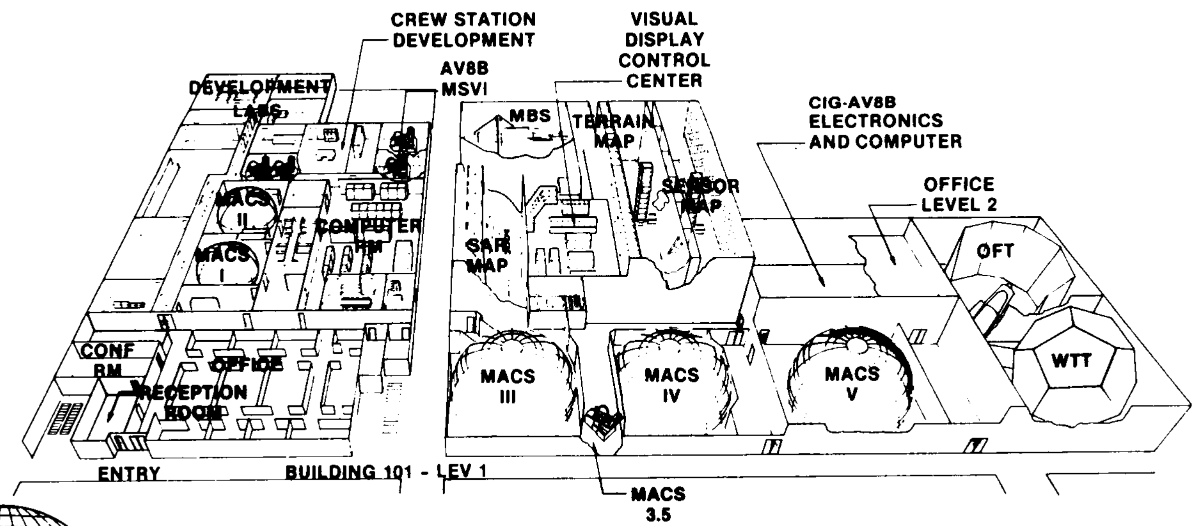
PLANNED IMPROVEMENTS:

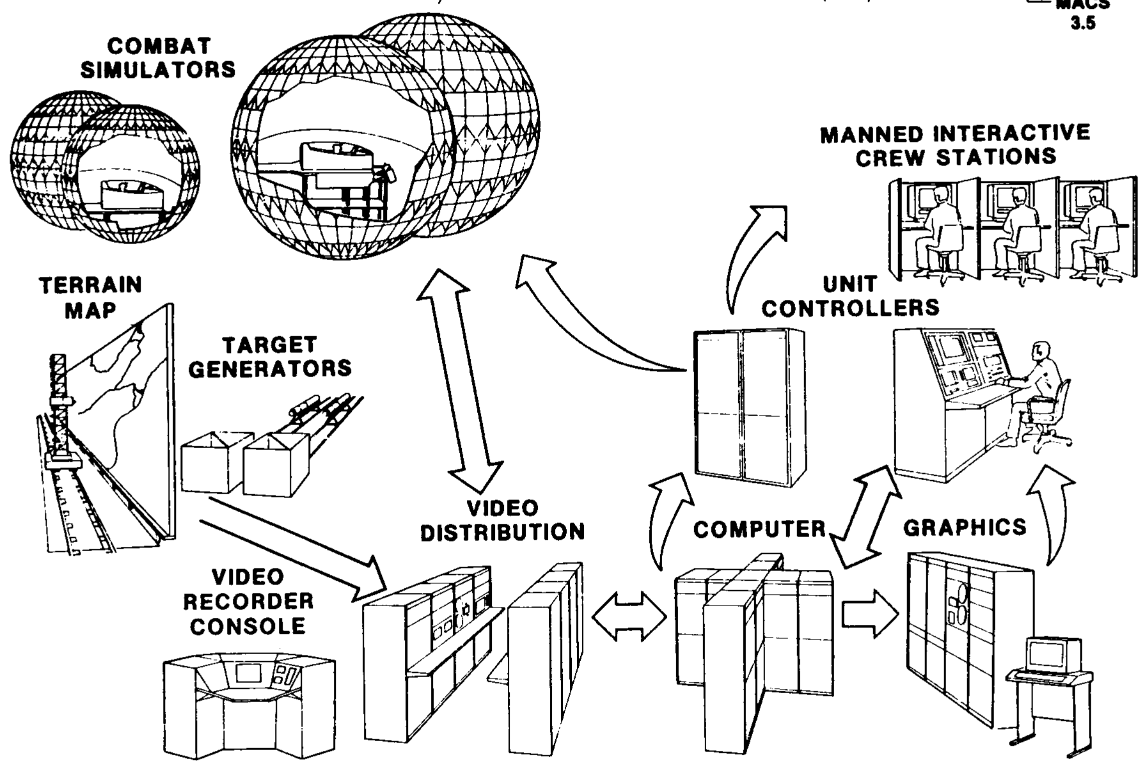
- Wide field of view
- Multivehicle air-to-air engagements

CONSTRAINTS: g duration; field of view

LOCAL INFORMATION CONTACT: Paul E. Blatt, AFWAL/FIGD, Wright-Patterson Air Force Base, OH 45433, (513) 255-5474.

# MANNED AIR COMBAT SIMULATION FACILITY



<table>
<tr><td rowspan="3">McDonnell Aircraft Company, St. Louis, MO</td><td colspan="2">HIGH PERFORMANCE AIRCRAFT</td><td>COMPARABLE FACILITIES</td></tr>
<tr><td>DATE BUILT/UPGRADED: 1969, 1970, 1974, 1977, 1980<br>REPLACEMENT COST:</td><td rowspan="2">MOTION: Fixed<br>Degrees of Freedom:<br>Linear Displacement:<br>g's:</td><td rowspan="2">None</td></tr>
<tr><td>OPERATIONAL STATUS:<br>1 or 2 shifts per day</td></tr>
<tr><td>Manned Air Combat Simulators, #1, #2, #3, #4, and #5</td><td>SYSTEMS SIMULATED:<br>Aircraft Type(s): Any single-seat aircraft (currently F-15, FA-18)<br>No. of Crew Stations: 1<br>ATC: Yes<br>Other: Flown singularly or with CGI, 1–4 other MACS, and/or 8 manned interactive cockpits</td><td colspan="2">VISUAL: Day, Dusk, Color<br>Field of View: 360°H; 300°V<br>Image Generation: MCAIR<br>Multiple-Model Point Light Terrain Map or Flying Spot Scanner<br>Image Presentation: Multiple valve (Virtual Image Optics) forward field of view, servoed CRT projection optics<br>HOST COMPUTER SYSTEM:<br>CDC Cyber 170-875</td></tr>
</table>

TYPICAL R&D PROGRAMS:

- The Manned Air Combat Simulators (MACSs) are used for hardware and software development. The simulator is collocated with the avionics development lab and actual flight hardware, and software can be flown in the simulator before actual flight. Cockpit design and human factors evaluations are done primarily in the simulator.
- Used for proof-of-concept testing and evaluation where multiplane environment is required.

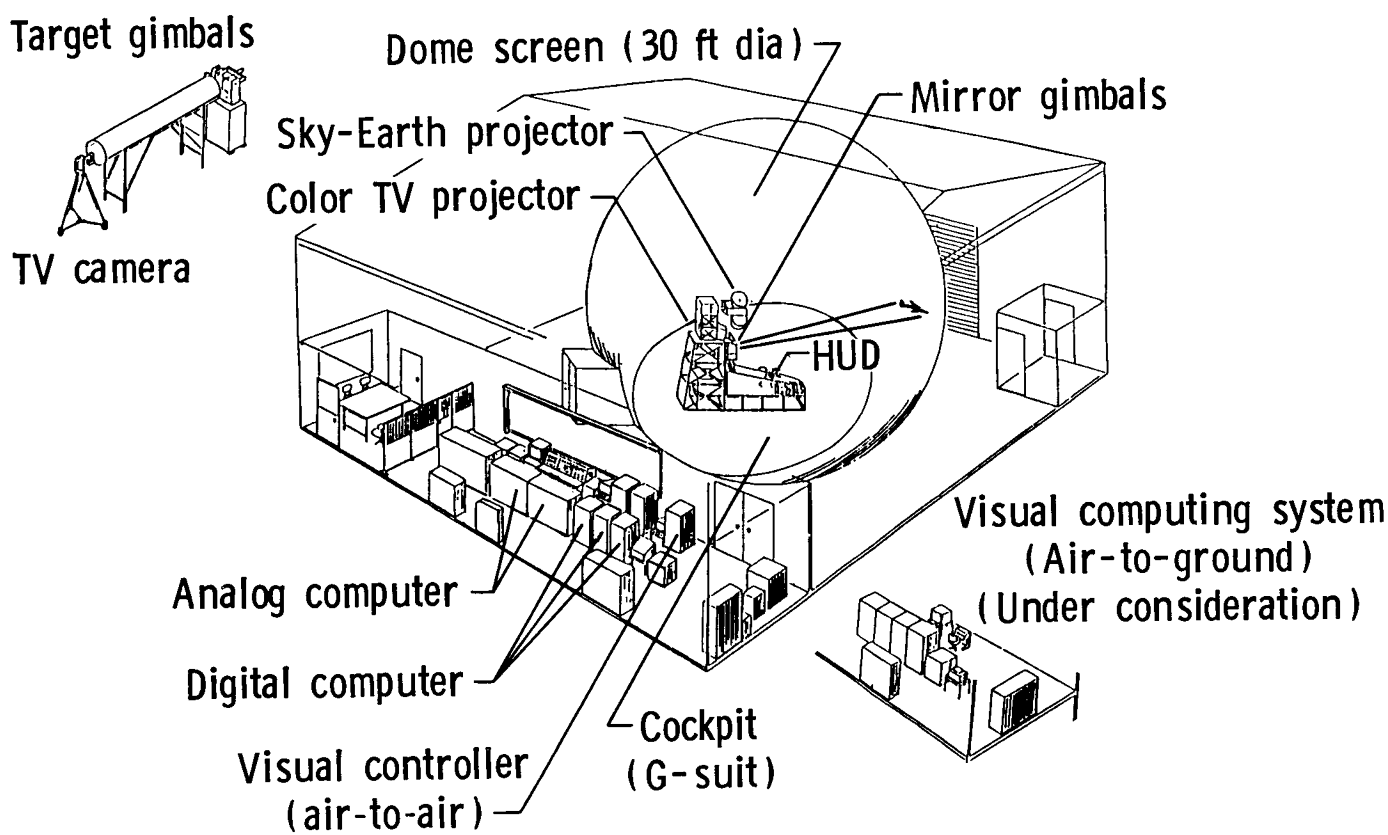
PLANNED IMPROVEMENTS: Computer image generation capability will be added to provide significantly improved low-altitude flight capability.

CONSTRAINTS:

- Experiencing the physiological factors of tactical fighters.
- High detail ground scene limited to forward 60° field of view.

LOCAL INFORMATION CONTACT: L. E. Ross, McDonnell Aircraft Company, P.O. Box 516, St. Louis, MO 63166, (314) 233-6800.

# FHI FLIGHT SIMULATOR



| Japan–Fuji Heavy Industries | HIGH PERFORMANCE AIRCRAFT | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1981<br>**REPLACEMENT COST:** $4M<br>**OPERATIONAL STATUS:** 1 shift per day | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | McDonnell Douglas: MACS |
| Flight Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>All types of fighter aircraft and V/STOL transports<br>**No. of Crew Stations:** 1<br>**ATC:** No<br>**Other:** HUD | **VISUAL:**<br>**Field of View:** ±90° Horiz, +65, -35 vert<br>**Image Generation:** Sky/Earth Projector, Japan Radio Co.; TV Camera, Hitachi Denshi Co.; Target Gimbal, Miyama & Co.<br>**Image Presentation:** Color TV projector<br>Manufacturer: General Electric Co.<br>Type: PJ 5050<br>**HOST COMPUTER SYSTEM:**<br>EAI 3200/2000 Hybrid System | |

TYPICAL R&D PROGRAMS:

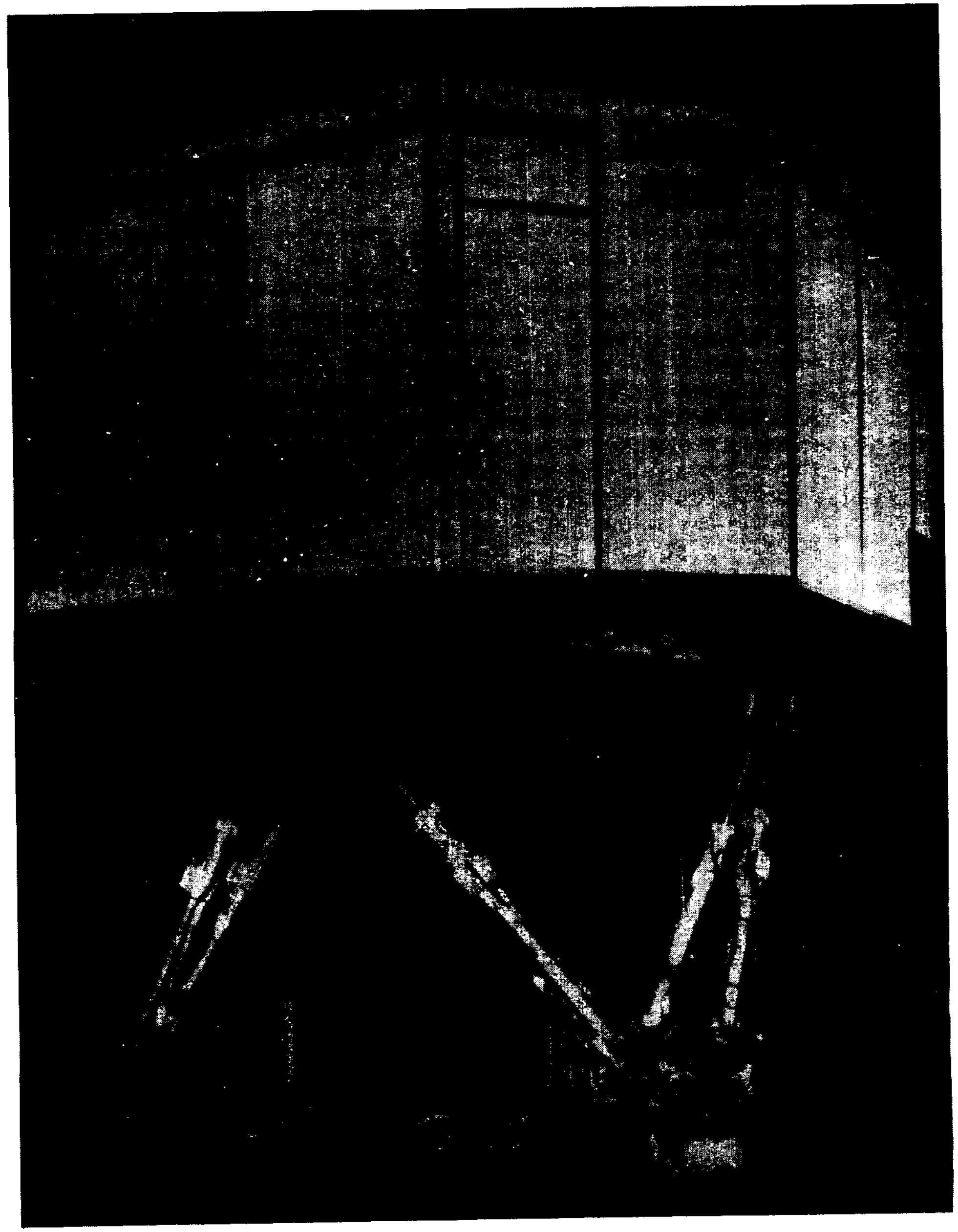
- RSS system for transport
- Flying quality study for jet V/STOL aircraft
- Integrated flight, fire, and propulsion control
- Flight control system for RPV

PLANNED IMPROVEMENTS:

- Flight table
- Visual system (CGI infinity display)
- Motion cue capability
- Digital computer

CONSTRAINTS:

LOCAL INFORMATION CONTACT: Akitoshi Nagao, General Manager, Aircraft Engineering Div., Fuji Heavy Industries, Ltd., 1-1-11 Yonan Utsunomiya Tochigi 320 Japan, phone: 0286-58-1111.



| NASA–Ames Research Center, Moffett Field, CA | VEHICLE SPECIFIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1983<br>**REPLACEMENT COST:** $5.1M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Moving<br>**Degrees of Freedom:** 6<br>**Linear Displacement:** (in)<br>Vert: ±70; long: ±53; lat: ±45<br>**g's:** ±0.8, ±0.7, ±0.7 | Boeing, WA:<br>Multipurpose Cab |
| Boeing 727 Flight Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** B727<br>**No.of Crew Stations:** 3 plus 1 observer<br>**ATC:** Yes<br>**Other:** Ground crew, servicing, and pushback | **VISUAL:**<br>**Field of View:** 30°V, 85°H<br>**Image Generation:** Link and Miles Image II<br>**Image Presentation:**<br>Manufacturer: Link and Miles<br>Type: Image II<br>**HOST COMPUTER SYSTEM:**<br>SEL 32/77, Sanders "7" Display | |

TYPICAL R&D PROGRAMS:

- Objective assessment of pilot performance
- Fatigue in short-haul operations

PLANNED IMPROVEMENTS: Daylight visual.

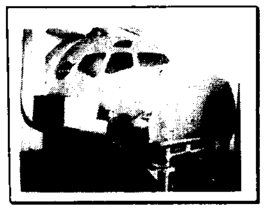
CONSTRAINTS: Constrained to motion system limits and power to simulator cab.

LOCAL INFORMATION CONTACT: Bob Shiner, Facility Manager, Mail Stop 257-1, NASA–Ames Research Center, Moffett Field, CA 94035, (415) 965-6279.

# DC-9/CDTI FULL WORKLOAD SIMULATOR

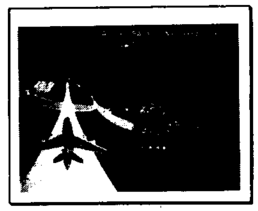
**PURPOSE**

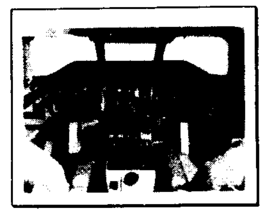
FULL WORKLOAD SIMULATOR FOR AIRCRAFT RETROFIT WITH COCKPIT DISPLAY OF TRAFFIC INFORMATION



DC-9 AIRCRAFT

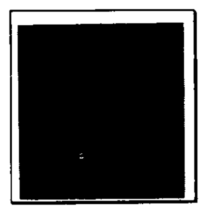
- SHORT-MEDIUM RANGE
- SUBSONIC JET TRANSPORT
- TWIN ENGINES
- T — TAIL
- TWO MAN CREW CAPABILITY





DC-9/CDTI SIMULATOR

- CONVENTIONAL INSTRUMENTATION
- HEADS DOWN CAPABILITY ONLY
- FULL WORKLOAD
- CDTI DISPLAY ON WEATHER RADAR SCOPE



TYPICAL CDTI DISPLAY WITH TOUCH PANEL CONTROLS

| | | | |
|---|---|---|---|
| NASA–Langley Research Center, Hampton, VA | **VEHICLE SPECIFIC FLIGHT DECKS** | | **COMPARABLE FACILITIES** |
| | **DATE BUILT/UPGRADED:** 1983<br>**REPLACEMENT COST:** $4M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | None |
| DC-9 Full Workload Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Complete DC-9 with Advanced CDTI Display<br>**No. of Crew Stations:** 1 (pilot and copilot)<br>**ATC:** Yes<br>**Other:** | **VISUAL:** None<br>**Field of View:**<br>**Image Generation:**<br>**Image Presentation:**<br>**HOST COMPUTER SYSTEM:**<br>CDC Cyber 175 with adage color stroke display generators | |

TYPICAL R&D PROGRAMS:

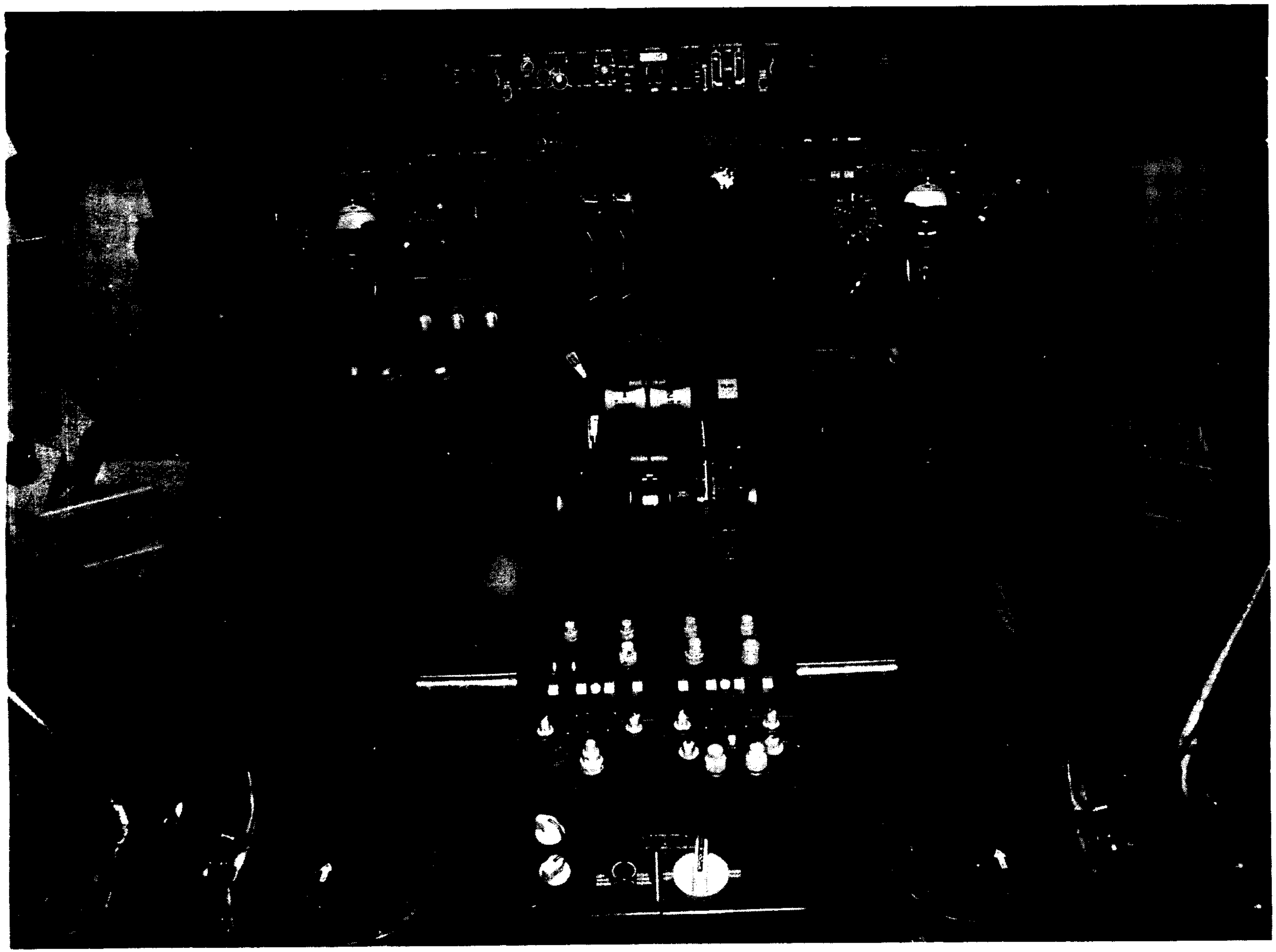
- Cockpit display of traffic information
- Distributive management of ATC functions

PLANNED IMPROVEMENTS: Visual window with terrain board.

CONSTRAINTS: No motion capability.

LOCAL INFORMATION CONTACT: B. R. Ashworth, NASA–Langley Research Center, Hampton, VA 23665, (804) 865-3874.

**BOEING COMMERCIAL AIRPLANE COMPANY**
**FLIGHT SYSTEMS LABORATORY 737-300 ENGINEERING CAB**



| The Boeing Company, Seattle, WA | VEHICLE SPECIFIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1980/1983<br>**REPLACEMENT COST:** $3.1M<br>**OPERATIONAL STATUS:** 2 shifts per day | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | None |
| Flight Systems Laboratory<br><br>737-300 Engineering Cab | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** 737-300<br><br>**No. of Crew Stations:** 2 (pilot, copilot)<br><br>**ATC:** Yes (intercom)<br><br>**Other:** | **VISUAL:** Day, Dusk, Night, Color<br>**Field of View:** 47.3°H; 35.6°V<br><br>**Image Generation:** Evans & Sutherland CT5-CGI<br><br>**Image Presentation:**<br>Manufacturer: Evans & Sutherland<br>Type: CGI–Beamsplitter/Mirror<br><br>**HOST COMPUTER SYSTEM:** Harris H800 and (2) Harris Slash front-end processors selectable from five equivalent systems by electronic switching | |

TYPICAL R&D PROGRAMS:

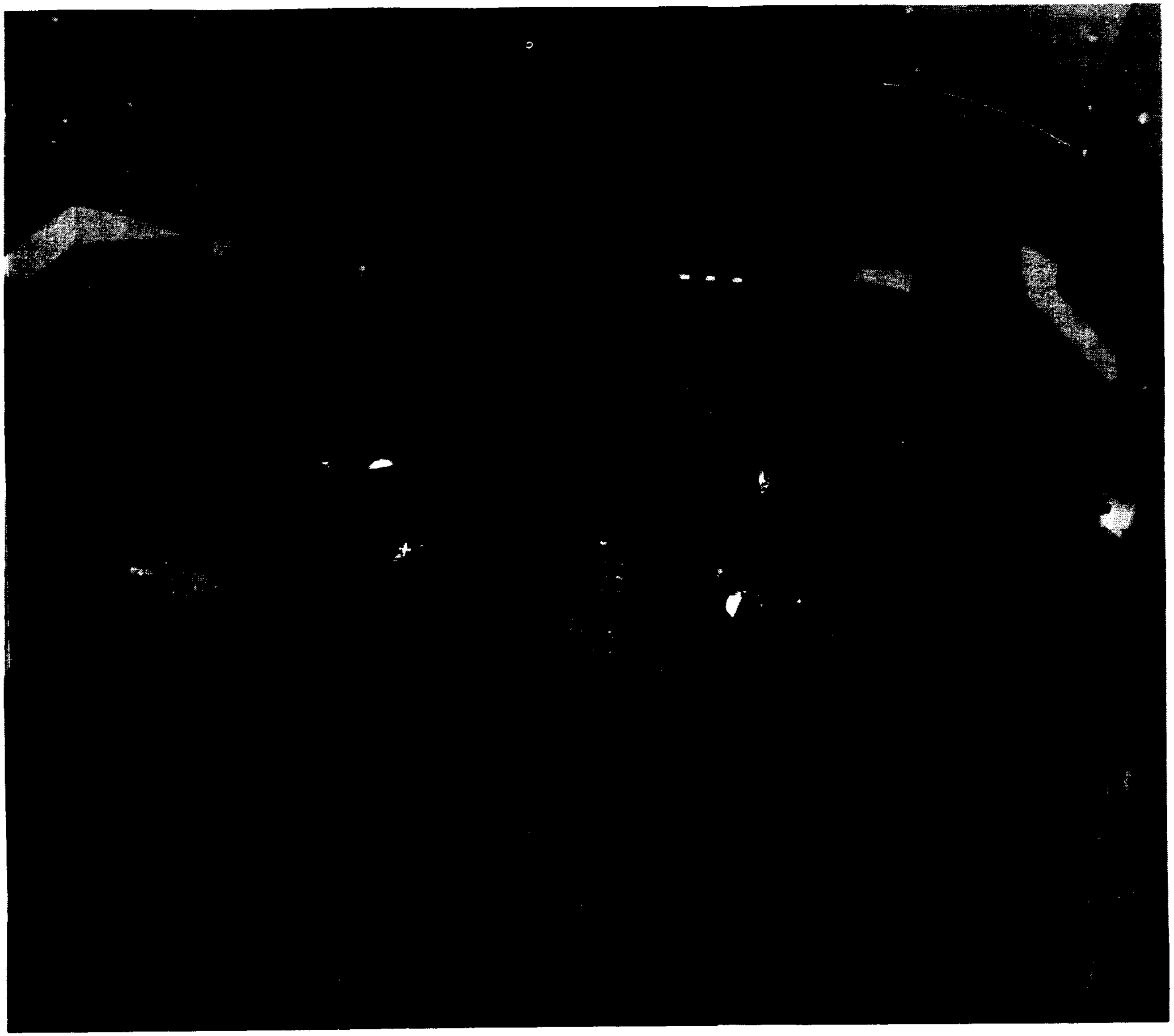
- Avionics development
- Pilot evaluations
- Workload studies
- Certification

PLANNED IMPROVEMENTS: Ongoing changes as required by airplane programs.

CONSTRAINTS: Two vision viewpoints shared between this cab and two others by scheduling.

LOCAL INFORMATION CONTACT: C. E. Phillips, Boeing Computer Services Company, Mail Stop 66-22, P.O. Box 24346, Seattle, WA 98124, (206) 237-7872.

BOEING COMMERCIAL AIRPLANE COMPANY
FLIGHT SYSTEMS LABORATORY SYSTEMS AND WORKLOAD CAB



| | VEHICLE SPECIFIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| The Boeing Company, Seattle, WA | **DATE BUILT/UPGRADED:** 1980<br>**REPLACEMENT COST:** $3.5M<br>**OPERATIONAL STATUS:** 2 shifts per day | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | None |
| Flight Systems Laboratory<br><br>Systems and Workload Cab | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** 757, 767<br><br>**No. of Crew Stations:** 2 (pilot, copilot)<br><br>**ATC:** Yes (intercom)<br><br>**Other:** Fully accurate 757 flight deck and changeable overhead systems for 767 instrument configuration | **VISUAL:** Day, Dusk, Night, Color<br>**Field of View:** 48.1°H, 36.1°V<br><br>**Image Generation:** Evans & Sutherland CT5-CGI<br><br>**Image Presentation:**<br>Manufacturer: Evans & Sutherland<br>Type: CGI–Beamsplitter/Mirror<br><br>**HOST COMPUTER SYSTEM:** | |

TYPICAL R&D PROGRAMS:

- Workload studies
- Avionics display development
- Pilot evaluations
- Certification

PLANNED IMPROVEMENTS: Maintain currency with 757/767 instrumentation.

CONSTRAINTS: Two vision viewpoints shared between this cab and two others by scheduling.

LOCAL INFORMATION CONTACT: C. E. Phillips, Boeing Computer Services Company, Mail Stop 66-22, P.O. Box 24346, Seattle, WA 98124, (206) 237-7872.

| | | | |
|---|---|---|---|
| The Boeing Company, Seattle, WA | **VEHICLE SPECIFIC FLIGHT DECKS** | | **COMPARABLE FACILITIES** |
| | **DATE BUILT/UPGRADED:** 1968/1983<br>**REPLACEMENT COST:** $3.1M<br>**OPERATIONAL STATUS:** 10 hr per week | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | None |
| Commercial Airplane Company<br><br>Flight Systems Laboratory<br><br>747 Cab | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** 747<br>**No. of Crew Stations:** 3<br>(pilot, copilot, flight engineer)<br>**ATC:** Yes (intercom)<br>**Other:** Sound | **VISUAL:**<br>**Field of View:** None<br>**Image Generation:** None<br>**Image Presentation:** None<br><br>**HOST COMPUTER SYSTEM:** Harris H800 and (1) Harris Slash 6 front-end processor selectable from five equivalent systems by electronic switching | |

TYPICAL R&D TASKS:

- Product improvement
- Avionics development
- Pilot evaluations

PLANNED IMPROVEMENTS: Ongoing changes/additions as required by airplane development programs.

CONSTRAINTS: No out-the-window vision system.

LOCAL INFORMATION CONTACT: C. E. Phillips, Boeing Computer Services Company, Mail Stop 66-22, P.O. Box 24346, Seattle, WA 98124, (206) 237-7872.

| Hughes Aircraft Company, Los Angeles, CA | VEHICLE SPECIFIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1979/1984<br>**REPLACEMENT COST:** $1.5M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | Japan–Mitsubishi: Advanced Technology Flight Simulator |
| Advanced Fighter Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Two advanced fighter cockpits similar in size to the F/A-18 and F-14 rear seater<br>**No. of Crew Stations:** 2<br>**ATC:** No<br>**Other:** Various control input and display output devices | **VISUAL:**<br>**Field of View:**<br>**Image Generation:** GTI Poly 2000; E&S MPS; STC IIS Model 70<br>**Image Presentation:**<br>Manufacturer: Aqua Star, Hughes<br>Type: Projection TV, DO HUD<br>**HOST COMPUTER SYSTEM:**<br>Two VAX 11/780 computers and raster graphics | |

TYPICAL R&D PROGRAMS:

- Human factors analysis
- Control and display evaluation
- System effectiveness evaluation
- Simulation and modeling

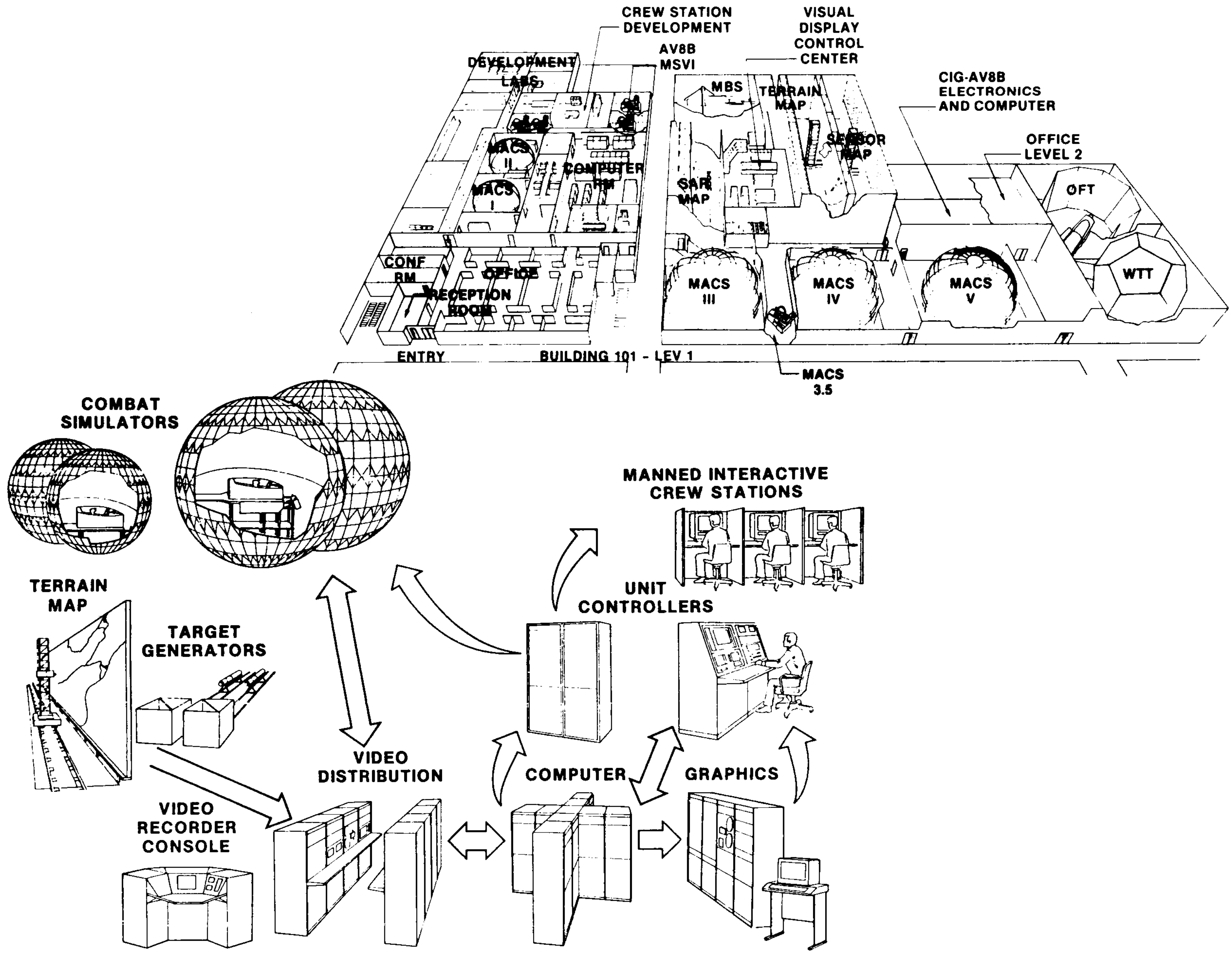
PLANNED IMPROVEMENTS:

- Voice I/O
- Force feel
- "G" seat
- Touch panel

CONSTRAINTS: Limited only by power of computers and graphic equipment.

LOCAL INFORMATION CONTACT: M. L. Hershberger, Hughes Aircraft Co., R1/C320, El Segundo, CA, (213) 648-9503.

# MANNED AIR COMBAT SIMULATION FACILITY



| | VEHICLE SPECIFIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| McDonnell Aircraft Company, St. Louis, MO | **DATE BUILT/UPGRADED:** 1976<br>**REPLACEMENT COST:**<br>**OPERATIONAL STATUS:** 1 shift per day | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | Hughes Aircraft: Advanced Flight Simulator |
| F/A-18 Developmental Simulator (MACS 3.5) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** F/A-18<br>**No.of Crew Stations:** 1<br>**ATC:** No<br>**Other:** | **VISUAL:** Dusk, Night, Color<br>**Field of View:** $\pm 30°H; \pm 25°V$<br>**Image Generation:** MDEC VITAL IV<br>**Image Presentation:**<br>Manufacturer: MDEC<br>Type: Virtual image, CRT<br>**HOST COMPUTER SYSTEM:**<br>CDC Cyber 170-875 | |

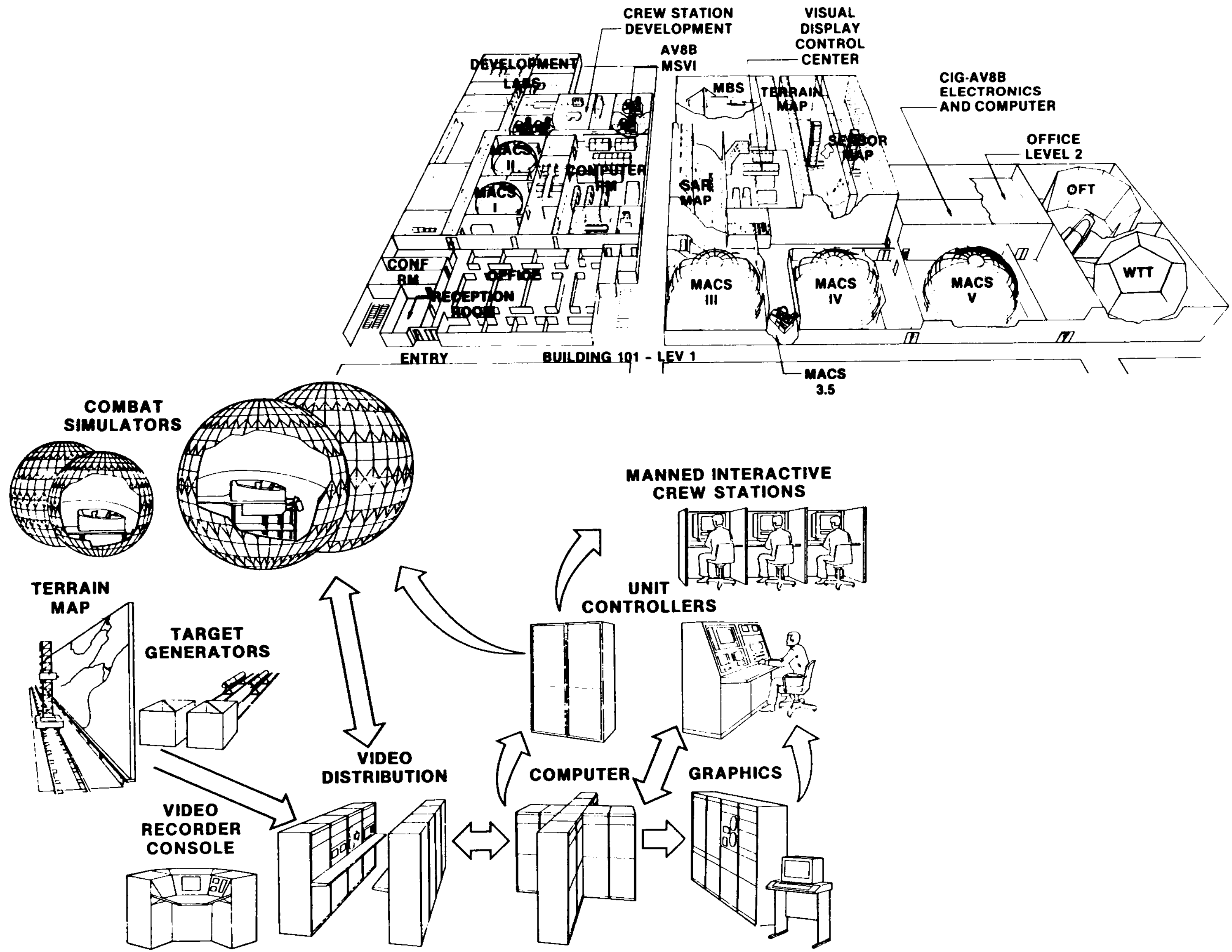
TYPICAL R&D PROGRAMS: The F/A-18 development simulator is used for hardware and software validation and verification. The simulator is collocated with the avionics development laboratory, and actual flight hardware and software can be flown in the simulator before actual flight.

PLANNED IMPROVEMENTS: None.

CONSTRAINTS: Limited visual capability; is *not* flown with MACS for multiplane evaluations.

LOCAL INFORMATION CONTACT: L. E. Ross, McDonnell Aircraft Company, P.O. Box 516, St. Louis, MO 63166, (314) 233-6800.

# MANNED AIR COMBAT SIMULATION FACILITY



| | | | |
|---|---|---|---|
| McDonnell Aircraft Company, St. Louis, MO | **VEHICLE SPECIFIC FLIGHT DECKS** | | **COMPARABLE FACILITIES** |
| | **DATE BUILT/UPGRADED:** 1978<br>**REPLACEMENT COST:**<br>**OPERATIONAL STATUS:** 1 shift per day | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | Hughes Aircraft: Advanced Flight Simulator |
| Manned Simulator VSTOL #1 (MSV-1) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** AV-8B<br>**No. of Crew Stations:** 1<br>**ATC:** No<br>**Other:** | **VISUAL:** Day, Dusk, Night, Color<br>**Field of View:** ±75°H; ±25°V<br>**Image Generation:** MDEC VITAL IV, CRT, light valve<br>**Image Presentation:**<br>Manufacturer: MDEC, MCAIR<br>Type: VITAL IV<br>**HOST COMPUTER SYSTEM:**<br>CDC Cyber 170-875 | |

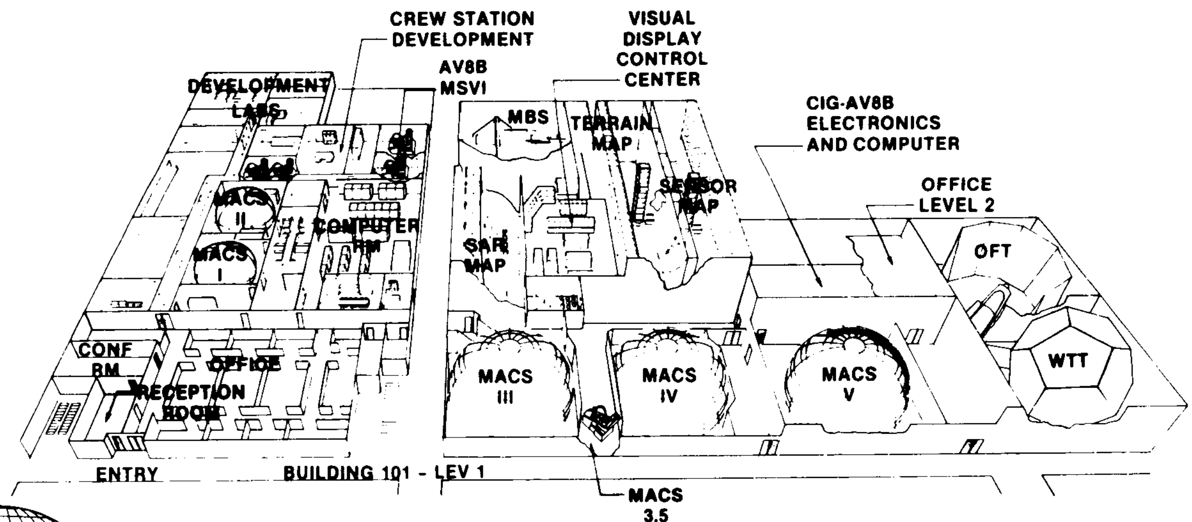
TYPICAL R&D PROGRAMS: The Manned Simulator V/STOL #1 is used for hardware and software validation and verification. The simulator is collocated with the avionics development laboratory, and actual flight hardware and software can be flown in the simulator before actual flight.

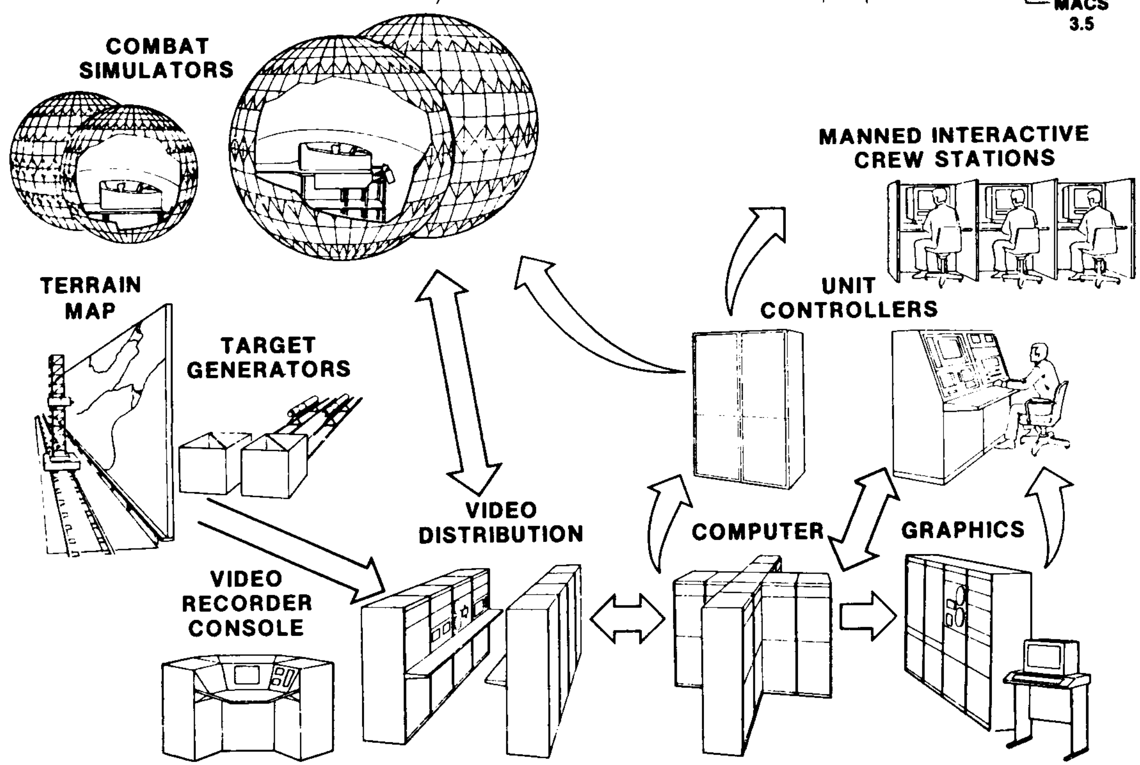
PLANNED IMPROVEMENTS: None.

CONSTRAINTS: Limited visual capability; is *not* flown with MACS for multiplane evaluations.

LOCAL INFORMATION CONTACT: L. E. Ross, McDonnell Aircraft Company, P.O. Box 516, St. Louis, MO 63166, (314) 233-6800.

# MANNED AIR COMBAT SIMULATION FACILITY



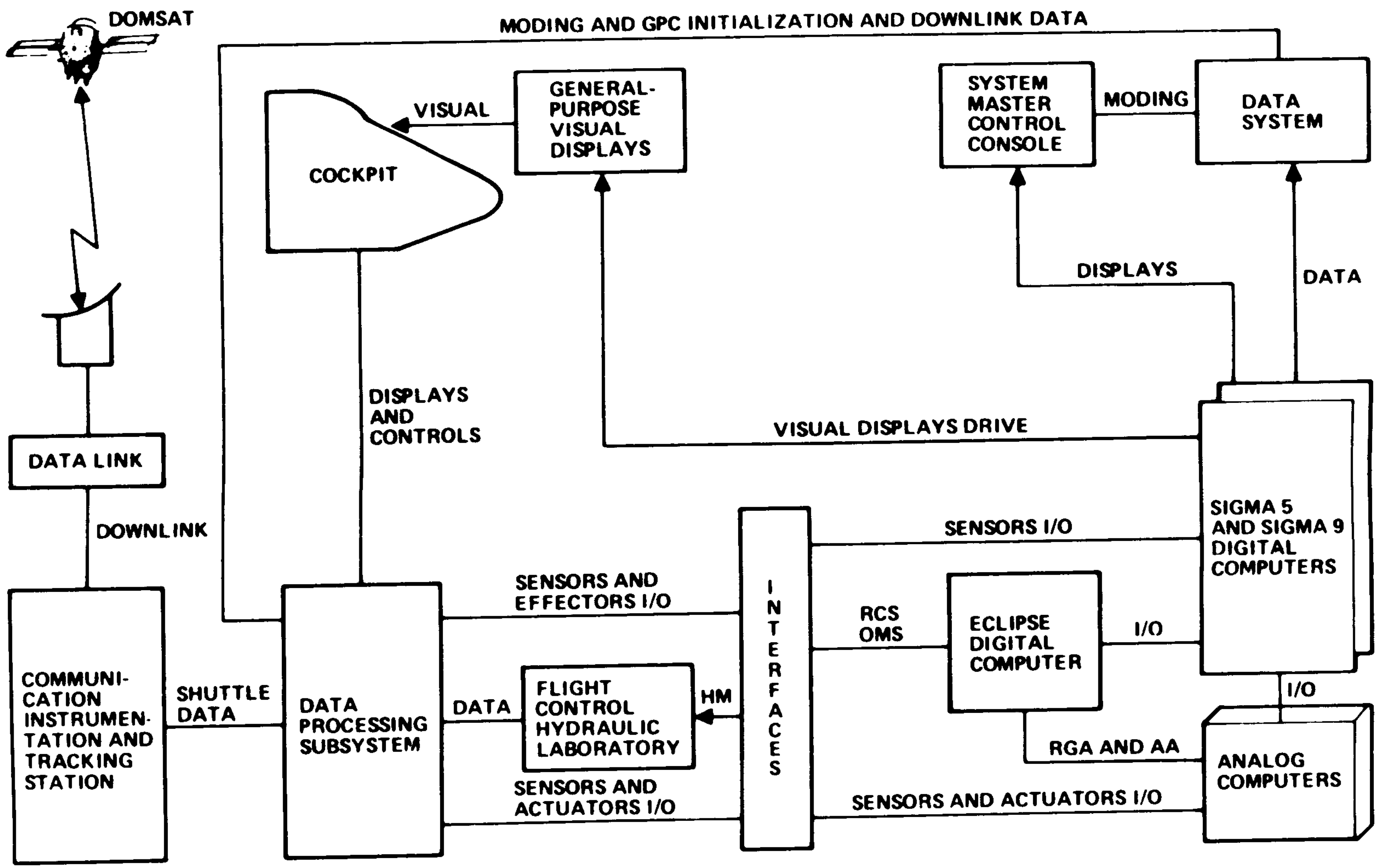
| McDonnell Aircraft Company, St. Louis, MO | VEHICLE SPECIFIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1980<br>**REPLACEMENT COST:**<br>**OPERATIONAL STATUS:** 1 shift per day | **MOTION:** Moving<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | Japan–Kawasaki: Simulator for Aircraft R&D |
| Manned Simulator V/STOL #2 | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>GR MK-V<br>**No. of Crew Stations:** 1<br>**ATC:** No<br>**Other:** | **VISUAL:** Day, Dusk, Night, Color<br>**Field of View:** ±75°H; ±25°V<br>**Image Generation:** MDEC VITAL IV, CRT, light valve<br>**Image Presentation:**<br>Manufacturer: MDEC, MCAIR<br>Type: VITAL IV<br>**HOST COMPUTER SYSTEM:**<br>CDC Cyber 170-875 | |

TYPICAL R&D PROGRAMS: The Manned Simulator V/STOL #2 is used for hardware and software validation and verification. The simulator is collocated with the avionics development laboratory, and actual flight hardware and software can be flown in the simulator before actual flight.

PLANNED IMPROVEMENTS: None.

CONSTRAINTS: Limited visual capability; is *not* flown with MACS for multiplane evaluations.

LOCAL INFORMATION CONTACT: L. E. Ross, McDonnell Aircraft Company, P.O. Box 516, St. Louis, MO 63166, (314) 233-6800.


DOMSAT
MODING AND GPC INITIALIZATION AND DOWNLINK DATA
COCKPIT
VISUAL
GENERAL-PURPOSE VISUAL DISPLAYS
SYSTEM MASTER CONTROL CONSOLE
MODING
DATA SYSTEM
DISPLAYS
DATA
DISPLAYS AND CONTROLS
VISUAL DISPLAYS DRIVE
DATA LINK
DOWNLINK
SIGMA 5 AND SIGMA 9 DIGITAL COMPUTERS
SENSORS I/O
SENSORS AND EFFECTORS I/O
I N T E R F A C E S
RCS OMS
ECLIPSE DIGITAL COMPUTER
I/O
I/O
COMMUNI-CATION INSTRUMEN-TATION AND TRACKING STATION
SHUTTLE DATA
DATA PROCESSING SUBSYSTEM
DATA
FLIGHT CONTROL HYDRAULIC LABORATORY
HM
RGA AND AA
ANALOG COMPUTERS
SENSORS AND ACTUATORS I/O
SENSORS AND ACTUATORS I/O

| | VEHICLE SPECIFIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| Rockwell International, Downey, CA | **DATE BUILT/UPGRADED:** 1974<br>**REPLACEMENT COST:** $100M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | None |
| Space Shuttle Hardware and Software Evaluators | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>Space Shuttle Orbiter<br>**No. of Crew Stations:** 3<br>(2 pilots/station)<br>**ATC:** No<br>**Other:** Full avionic capability supported by a prototype data processing subsystem and prototype cockpit displays and controls | **VISUAL:**<br>**Field of View:** Forward left window<br>**Image Generation:** CBS color camera<br>Ferrand optical probe<br>DEC PDP-11<br>**Image Presentation:** Eidophor projector<br>Manufacturer: Gretag<br>Type: EP-8SQ<br>**HOST COMPUTER SYSTEM:** Xerox Sigma 5 and 9 computers, Data General eclipse computers, and Electronic Associates, Inc., EAI-780 computers | |

TYPICAL R&D PROGRAMS:

- Flight control evaluation
- Guidance and navigation evaluation
- Aerosurface actuator evaluation
- Aeroflight assessment
- Integrated performance evaluation
- Orbital maneuvering vehicle
- Space station

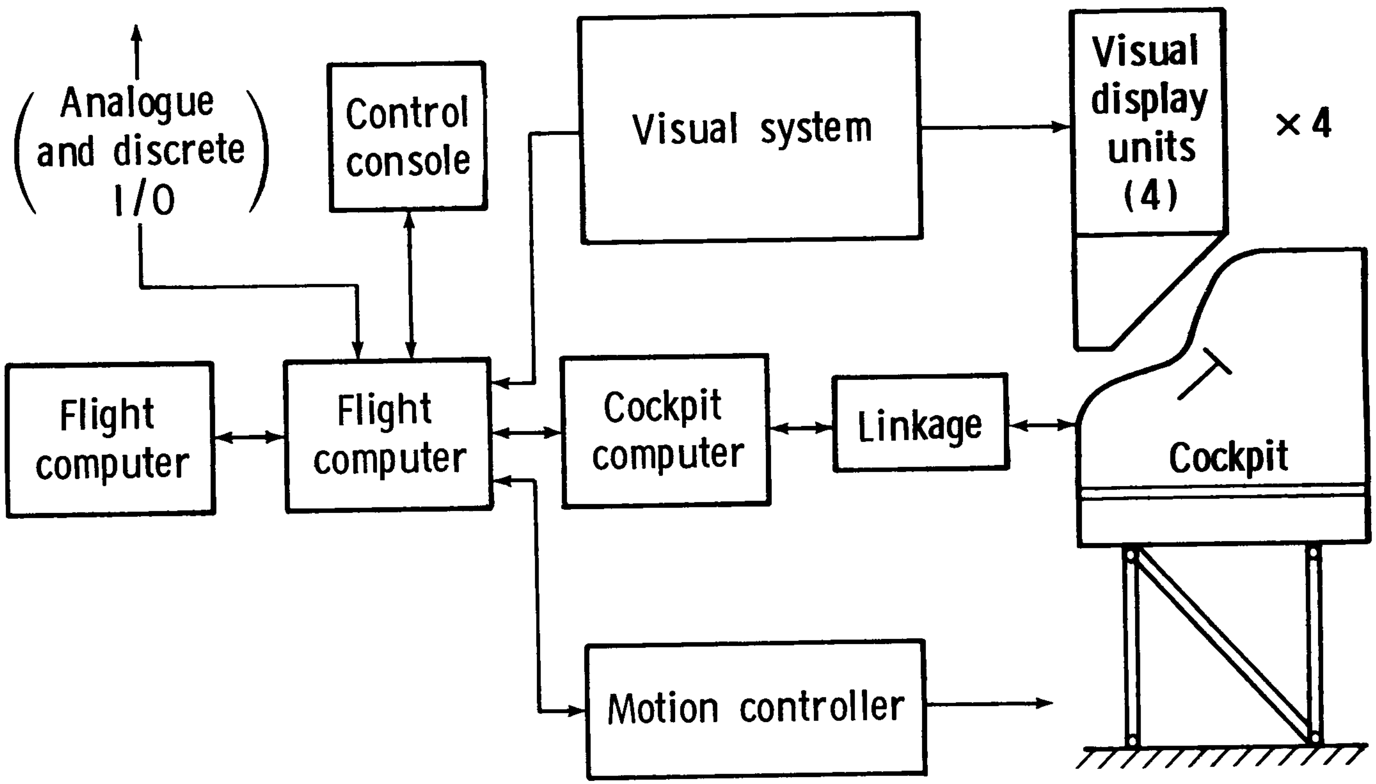
PLANNED IMPROVEMENTS:

- Host computer
- Visual system

CONSTRAINTS: Limited only by power of computers and visual equipment.

LOCAL INFORMATION CONTACT: J. M. Robertson, Rockwell International, D/298, Mail Code DA25, 12214 Lakewood Blvd., Downey, CA 90241, (213) 922-4245.

## SYSTEM BLOCK DIAGRAM OF NAL FLIGHT SIMULATOR



| Japan–National Aerospace Laboratory, Tokyo, Japan | VEHICLE SPECIFIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1984<br>**REPLACEMENT COST:** $4.3M<br>**OPERATIONAL STATUS:** 1984 | **MOTION:** Moving<br>**Degrees of Freedom:** 6<br>**Linear Displacement:** (ft)<br>Vert: 5.4; long: 6.5; lat: 6.8°<br>**g's:** 1.1 | NASA–ARC: 727 Flight Simulator |
| Flight Simulator for Research and Development | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>Medium to large transports<br>**No. of Crew Stations:** 2<br>**ATC:** No<br>**Other:** Designed mainly for development of NAL QSTOL experimental aircraft | **VISUAL:**<br>**Field of View:** 26°V, 90.5°H<br>**Image Generation:** Mitsubishi Precision Co. Computer-generated imagery<br>**Image Presentation:**<br>Manufacturer: Mitsubishi Precision Co.<br>Type: Infinity display<br>**HOST COMPUTER SYSTEM:** Eclipse MV/6000 and MV/8000; NWX-230 color graphics system (JRC) | |

TYPICAL R&D PROGRAMS:

- Assessment of flying qualities and development of airworthiness criteria
- Development of new concepts of guidance, AFCS, and cockpit display
- Safety analysis
- Pilot workload analysis

PLANNED IMPROVEMENTS: Visual system (enhancement of number of edges per raster).

CONSTRAINTS: Limited only by power of computer.

LOCAL INFORMATION CONTACTS: A. Watanabe and T. Bandow, NAL, 1880 Jindaiji-Cho, Chofu, Tokyo, Japan ZIP 182, phone: 0422-47-5911 (541).

| Japan—Mitsubishi Heavy Industries, Nagoya Aircraft Works | **VEHICLE SPECIFIC FLIGHT DECKS** | | **COMPARABLE FACILITIES** |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** Upgraded 1984<br>**REPLACEMENT COST:** $1M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | Hughes Aircraft: Advanced Flight Simulator |
| Flight Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>Advanced technology fighters<br>**No. of Crew Stations:** 1<br>**ATC:** No<br>**Other:** Integrated cockpit management, digital display, and side-stick controller | **VISUAL:** Day, Dusk, Color<br>**Field of View:**<br>**Image Generation:** Mitsubishi Precision Co. Computer-generated imagery<br>**Image Presentation:**<br>Manufacturer: Mitsubishi Precision Co.<br>Type: Infinity display<br>**HOST COMPUTER SYSTEM:**<br>SEL 32/75 | |

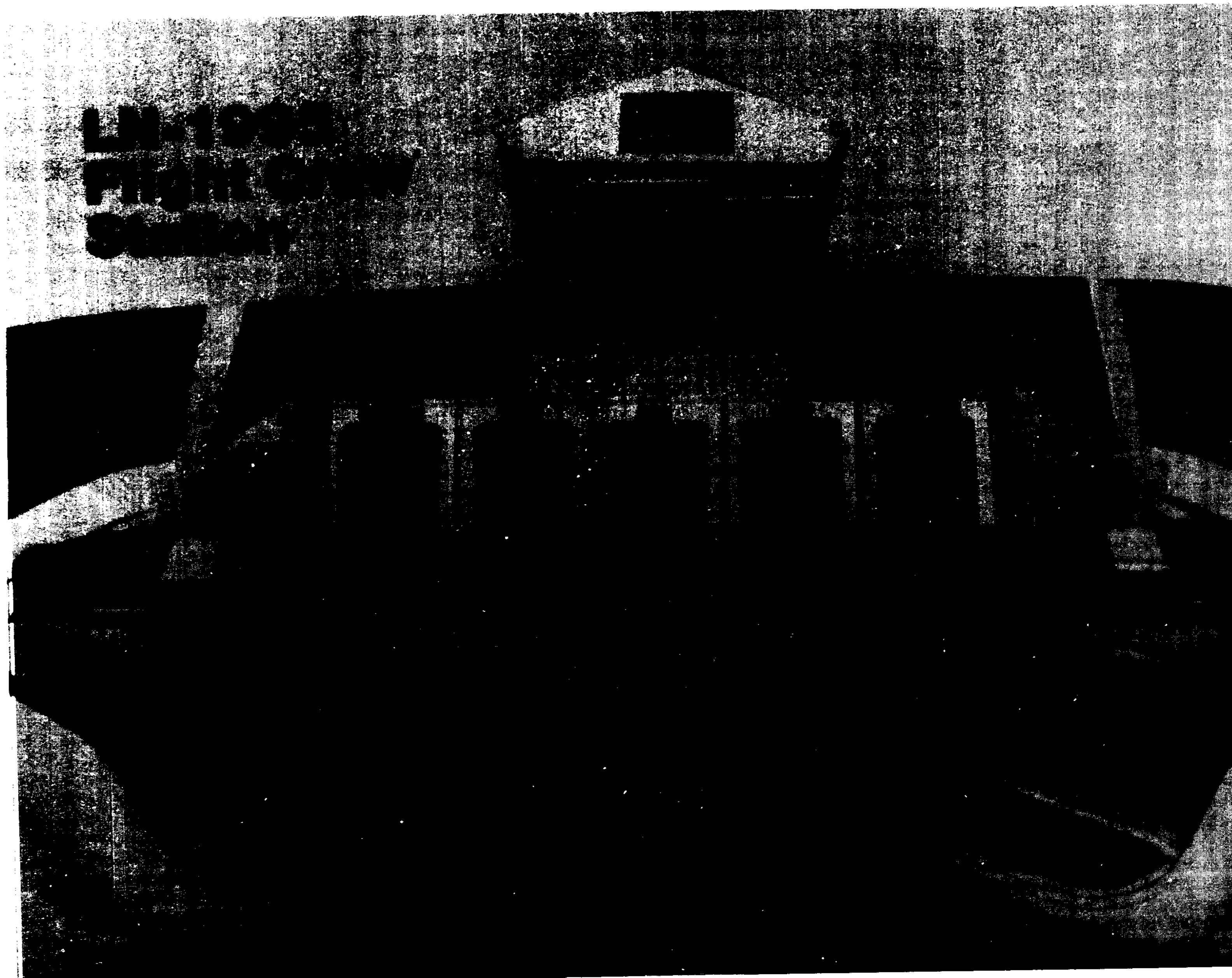
TYPICAL R&D PROGRAMS:

- Development of cockpit for advanced technology fighter
- Evaluation of CCV
- Handling quality of man/machine system

PLANNED IMPROVEMENTS: None.

CONSTRAINTS: Limited visual angle and no motion capability.

LOCAL INFORMATION CONTACT: K. Ochi, Structure and Equipment Research Section, First Engineering Dept., Nagoya Aircraft Works, Mitsubishi Heavy Industries, Ltd., 10, Oye-Cho, Minatoku, Nagoya, Japan.



| NASA–Ames Research Center, Moffett Field, CA | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1984<br>**REPLACEMENT COST:** $6.2M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Fixed<br>**Degrees of Freedom:** N/A<br>**Linear Displacement:** N/A<br>**g's:** N/A | Lockheed, GA: Advanced Concepts Flight Simulator |
| Advanced Concepts Flight Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Advanced Aircraft LN 1995<br>**No. of Crew Stations:** 2<br>**ATC:** Fully interactive in Denver terminal area.<br>**Other:** Advanced CRT displays with touch panels, voice I/O | **VISUAL:**<br>**Field of View:** 30°V, 45°H<br>**Image Generation:** Link and Miles Image II<br>**Image Presentation:**<br>Manufacturer: Link and Miles<br>Type: Image II<br>**HOST COMPUTER SYSTEM:**<br>SEL 32/77, VAX 11/780, Adage RDS 3000 Raster Graphics | |

TYPICAL R&D PROGRAMS: Evaluation of human performance prediction.

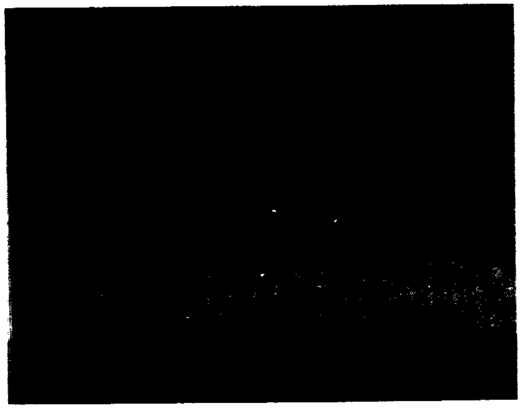
PLANNED IMPROVEMENTS:

- Daylight visual – four windows
- Motion system

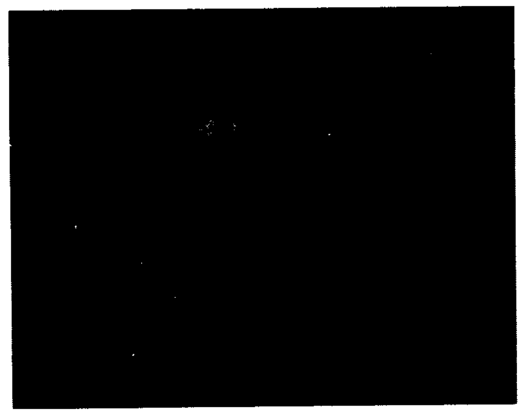
CONSTRAINTS: Limited by power of computers and graphics systems.

LOCAL INFORMATION CONTACT: Bob Shiner, Facility Manager, Mail Stop 257-1, NASA–Ames Research Center, Moffett Field, CA 94035, (415) 965-6279.

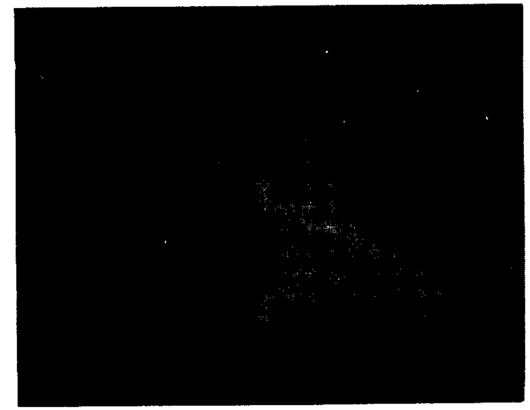
# AMES FLIGHT SIMULATOR FOR ADVANCED AIRCRAFT



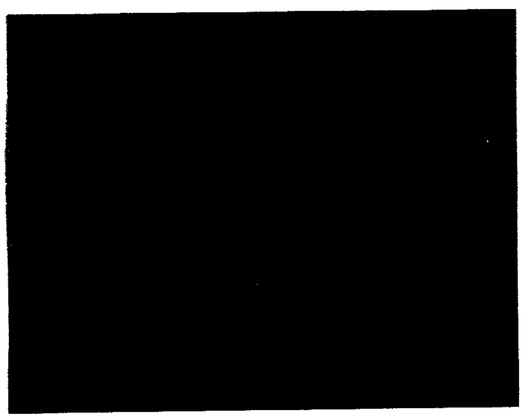
HANDLING QUALITIES AND FLIGHT DYNAMICS RESEARCH



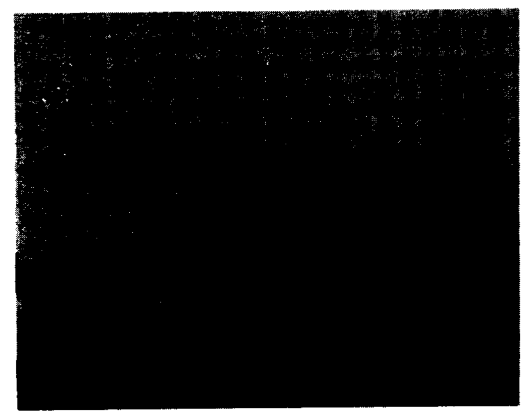
- LARGE AMPLITUDE 6 DOF MOTION SYSTEM (100 ft LATERAL)
- (INTERCHANGEABLE CABS AND WIDE FOV COMPUTER GENERATED IMAGERY PLANNED FOR 1985)



CONCEPT DEVELOPMENT FOR DOD



AIRWORTHINESS AND CERTIFICATION FOR CIVIL TRANSPORTS



DOD AIRCRAFT SYSTEMS DEVELOPMENT

| NASA–Ames Research Center, Moffett Field, CA | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1969<br>**REPLACEMENT COST:** $6M<br>**OPERATIONAL STATUS:** | **MOTION:** Moving<br>**Degrees of Freedom:** 6<br>**Linear Displacement:** (ft)<br>Vert: ±4.2; long: ±3.5; lat: ±40<br>**g's:** ±0.4, ±0.25, ±0.25 | U.K.–RAE (Bedford):<br>Advanced Flight Simulator |
| Flight Simulator for Advanced Aircraft (FSAA) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** OSRA, RSRA, F111, Shuttle, KC135, UH60, UH-1H, XV15<br>**No.of Crew Stations:** Two<br>**ATC:**<br>**Other:** | **VISUAL:** Day, Dusk, Night, Color<br>**Field of View:** VFA 48°H x 36.5°V, E&S 22°H x 22°V<br>**Image Generation:** Redifon/E&S Picture System I TV Camera, Model Board/Calligraphic<br>**Image Presentation:** Two-window collimated, color TV and HUD<br>Manufacturer: NASA–Ames Research Center<br>Type: 525 Raster Scan/Strobe Monitors<br>**HOST COMPUTER SYSTEM:**<br>Xerox Sigma 8 Computer | |

TYPICAL R&D PROGRAMS:

- Handling quality and flight dynamics research
- Aircraft concept development
- Aircraft systems development

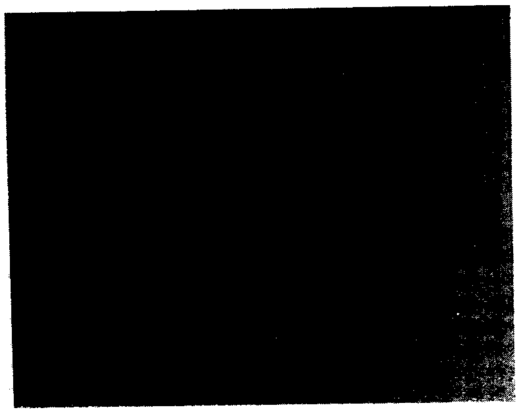
PLANNED IMPROVEMENTS:

- Installation of interchangeable cab concept
- Installation of CGI visual presentation system

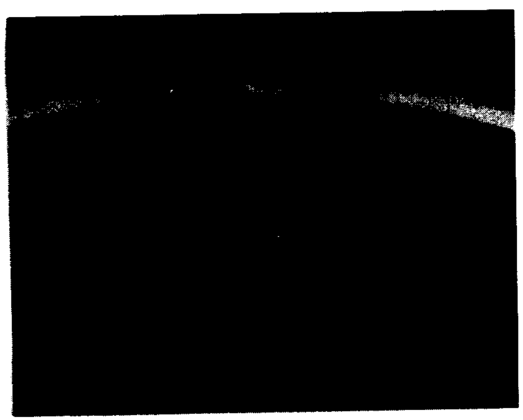
CONSTRAINTS: Limited only by power of computer.

LOCAL INFORMATION CONTACT: A. M. Cook, NASA–Ames Research Center, Mail Stop 243-1, Moffett Field, CA 94035, (415) 965-5162.

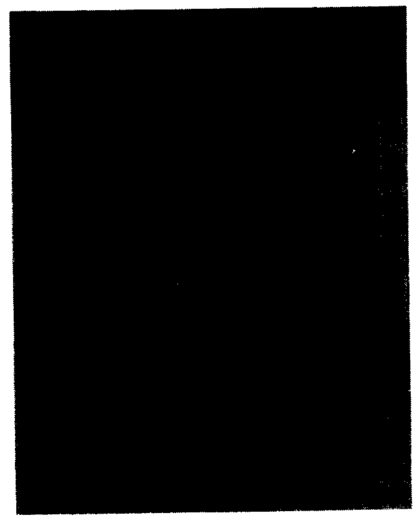
# AMES VERTICAL MOTION SIMULATOR



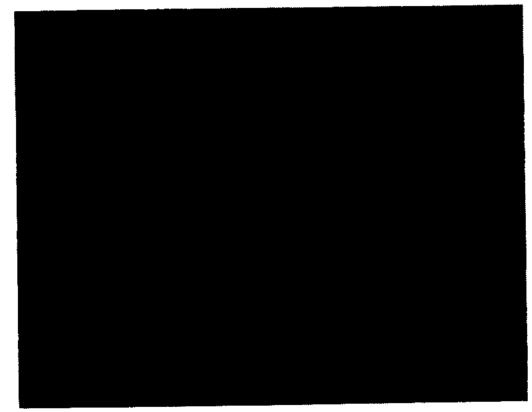
SPACE SHUTTLE
LANDING SYSTEMS
RESEARCH AND DEVELOPMENT



VTOL SHIPBOARD
LANDING RESEARCH



- INTERCHANGEABLE CABS
- WIDE FOV COMPUTER GENERATED IMAGERY
- LARGE AMPLITUDE 6 DOF MOTION SYSTEM (60 ft VERTICAL × 40 ft LATERAL)



ROTORCRAFT
HANDLING QUALITIES

CONCEPT DEVELOPMENT
FOR DOD

| | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| NASA–Ames Research Center, Moffett Field, CA | **DATE BUILT/UPGRADED:** 1979/1982<br>**REPLACEMENT COST:** $10M<br>**OPERATIONAL STATUS:** 2 shifts per day | **MOTION:** Moving<br>**Degrees of Freedom:** 6<br>**Linear Displacement:** (ft)<br>Vert: ±25; long: ±2.5; lat: ±17<br>**g's:** ±0.75, ±0.5, ±0.5 | None |
| Vertical Motion Simulator (VMS) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Shuttle, XV15, UH60, RSRA, YAV8B<br>**No.of Crew Stations:** 1 or 2<br>**ATC:**<br>**Other:** | **VISUAL:** Day, Dusk, Night, Color<br>**Field of View:** Each CGI Window, 48°H x 36.5°V<br>**Image Generation:** CGI-Singer Link and Evans & Sutherland; DIG 1, Full Color and Calligraphic<br>**Image Presentation:** Four-window collimated, color TV, and external HUD<br>Manufacturer: Singer Link and E&S Picture System<br>Type: 1024 Vertical Raster Scan and Strobe<br>**HOST COMPUTER SYSTEM:**<br>CDC 7600; Xerox Sigma 8; Xerox Sigma 7 | |

TYPICAL R&D PROGRAMS:

- Handling qualities and flight dynamics research
- Aircraft concept development
- Aircraft systems development

PLANNED IMPROVEMENTS:

- Installation of rotor system motion generator (RSMG)
- Installation of advanced cab and visual system (ACAVS)
- Installation of Evans & Sutherland CT5A image generator

CONSTRAINTS: None

LOCAL INFORMATION CONTACT: A. M. Cook, NASA–Ames Research Center, Mail Stop 243-1, Moffett Field, CA 94035, (415) 965-5162.

| NASA–Ames Research Center, Moffett Field, CA | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1963/1984<br>**REPLACEMENT COST:** $4M<br>**OPERATIONAL STATUS:** Being upgraded<br>Operational 1985 | **MOTION:** Moving<br>**Degrees of Freedom:** 6<br>**Linear Displacement:** (ft)<br>Vert: ±8.5; long: ±8.5; lat: ±9.0<br>**g's:** ±0.28, ±0.23, ±0.3 | Grumman:<br>LAMARS |
| 6 Degrees of Freedom | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>**No. of Crew Stations:**<br>**ATC:**<br>**Other:** | **VISUAL:**<br>**Field of View:** 48°H x 36.5°V<br>**Image Generation:** Redifon<br>TV Camera/Model Board<br>**Image Presentation:**<br>Manufacturer: Miratel<br>Type: B/W, 525 Line Raster<br>**HOST COMPUTER SYSTEM:**<br>Xerox Sigma 9 Computer | |

TYPICAL R&D PROGRAMS:

- Handling qualities and flight dynamics research
- VTOL hover and landings
- Simulation with 1 to 1 open-cockpit motion mode

PLANNED IMPROVEMENTS:

- Improved servo performance
- Tail-sitter VTOL capability

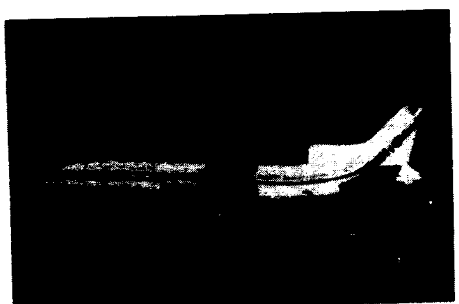
CONSTRAINTS: Limited only by power of computer.

LOCAL INFORMATION CONTACT: A. M. Cook, NASA–Ames Research Center, Mail Stop 243-1, Moffett Field, CA 94035, (415) 965-5162.

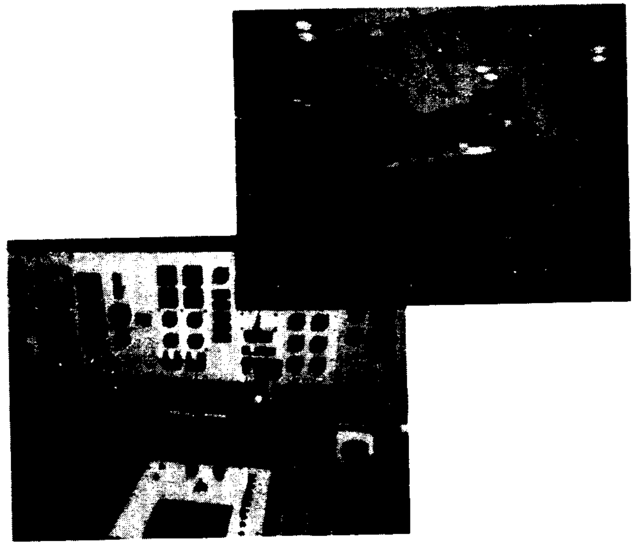
# VISUAL MOTION SIMULATOR

MUTLTIBODIED
TRANSPORT STUDIES

F-14 VALIDITY CUE FIDELITY STUDY

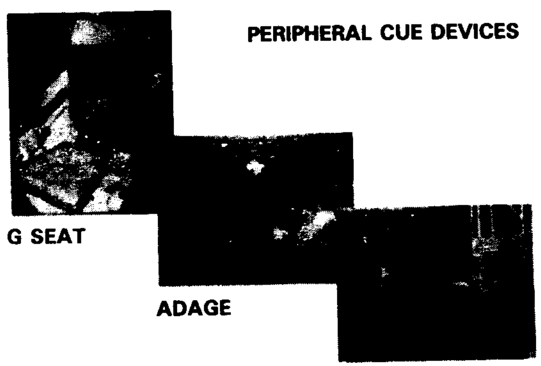


RELAXED STATIC STABILITY FOR INCREASED FUEL EFFICIENCY L1011



LEFT AND RIGHT COLLIMATING DISPLAYS
LEFT SIDE INSTRUMENTS — TRANSPORT
RIGHT SIDE INSTRUMENTS — HELICOPTER
LEFT — PROGRAMMABLE HYDRAULIC WHEEL, COLUMN, RUDDER
RIGHT — MECHANICAL CYCLIC CONTROLLER
AUDIO CUES

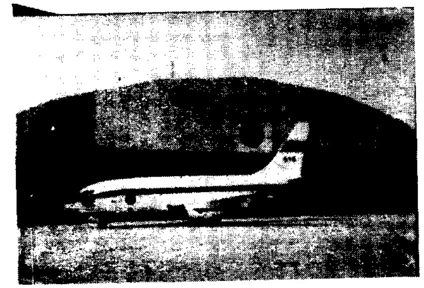
PERIPHERAL CUE DEVICES



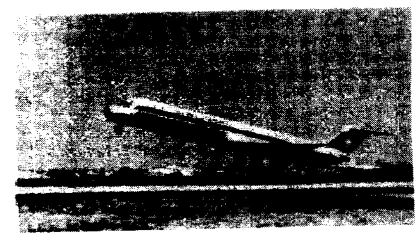
G SEAT

ADAGE

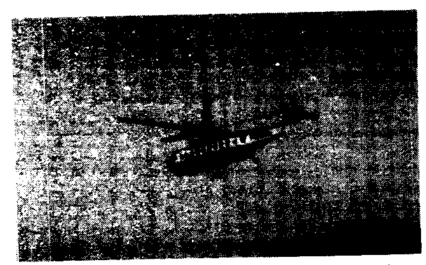
VLDS



737
SIMULATION REQUIREMENTS FOR DIRECTIONAL CONTROL ON RUNWAYS
HIGH-SPEED TURN-OFF STUDIES



DC-9
GROUND HANDLING CHARACTERISTICS ON DRY, FLOODED, AND ICY RUNWAYS



FOR VTOL IFR APPROACHES S 61

| NASA–Langley Research Center, Hampton, VA | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1971/1974/1976<br>**REPLACEMENT COST:** $1M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Moving<br>**Degrees of Freedom:** 6<br>**Linear Displacement:** (in)<br>Vert: 69; long: 96; lat: 96<br>**g's:** ±0.8 | Neth–NLR:<br>Moving Base<br>Flight Simulator |
| Visual Motion Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Numerous transports, helicopters, fighters, and GA aircraft<br>**No.of Crew Stations:** 2<br>**ATC:** Available<br>**Other:** G-seat, head-up and head-down graphics displays | **VISUAL:**<br>**Field of View:** 60° diagonal (both pilots)<br>**Image Generation:** Redifussion: Model Board<br>**Image Presentation:**<br>Manufacturer: Redifussion<br>Type: Duo-View<br>**HOST COMPUTER SYSTEM:**<br>CDC Cyber 175 with adage color graphics for head-down displays | |

TYPICAL R&D PROGRAMS:

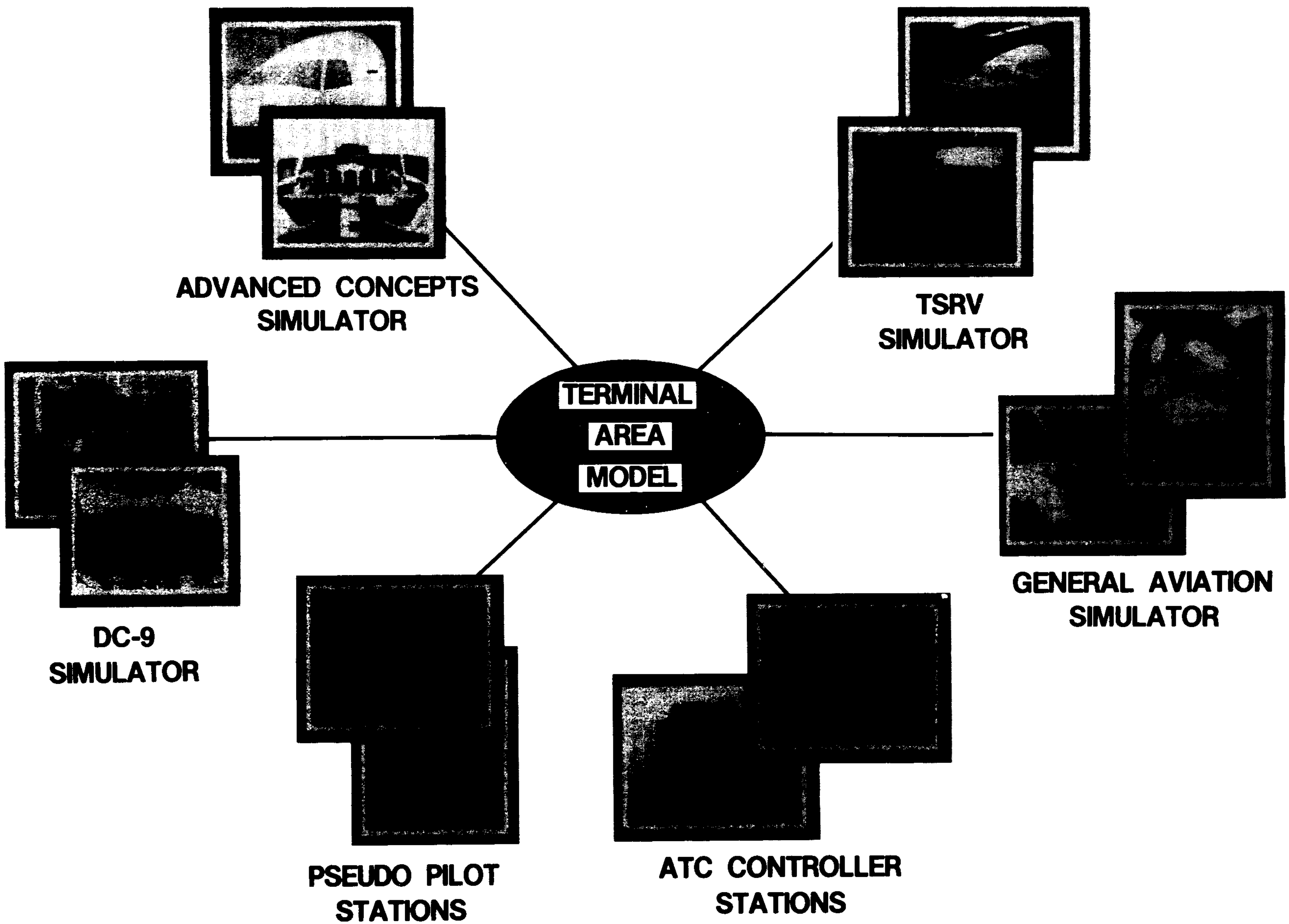
- Landing approach studies
- Directional control on runways
- Aircraft stability and control studies
- VTOL IFR approaches

PLANNED IMPROVEMENTS: None.

CONSTRAINTS: Research limited only by motion and visual limits.

LOCAL INFORMATION CONTACT: B. R. Ashworth, NASA–Langley Research Center, Hampton, VA 23665, (804) 865-3874.

# MISSION ORIENTED TERMINAL AREA SIMULATION



| NASA–Langley Research Center, Hampton, VA | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1983<br>**REPLACEMENT COST:** $1M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** N/A<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | GR–DFVLR: Air Traffic Management and Operations Simulator |
| Mission Oriented Terminal Area Simulation (MOTAS) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Business jets through heavy transports<br>**No. of Crew Stations:** Multiple simulators<br>**ATC:** 2 stations. Multiple routes and sectors for Denver terminal area<br>**Other:** Pseudo-pilot stations for control of computer generated aircraft | **VISUAL:**<br>**Field of View:** Standard ATC scope<br>**Image Generation:** Evans & Sutherland PS-300<br>**Image Presentation:**<br>Manufacturer: E&S<br>Type: Monochrome Controller Stations<br>**HOST COMPUTER SYSTEM:** CDC Cyber 175 (2) with PDP 11/44 for controller station graphics and PDP 11/34 for pseudo-pilot stations | |

TYPICAL R&D PROGRAMS:

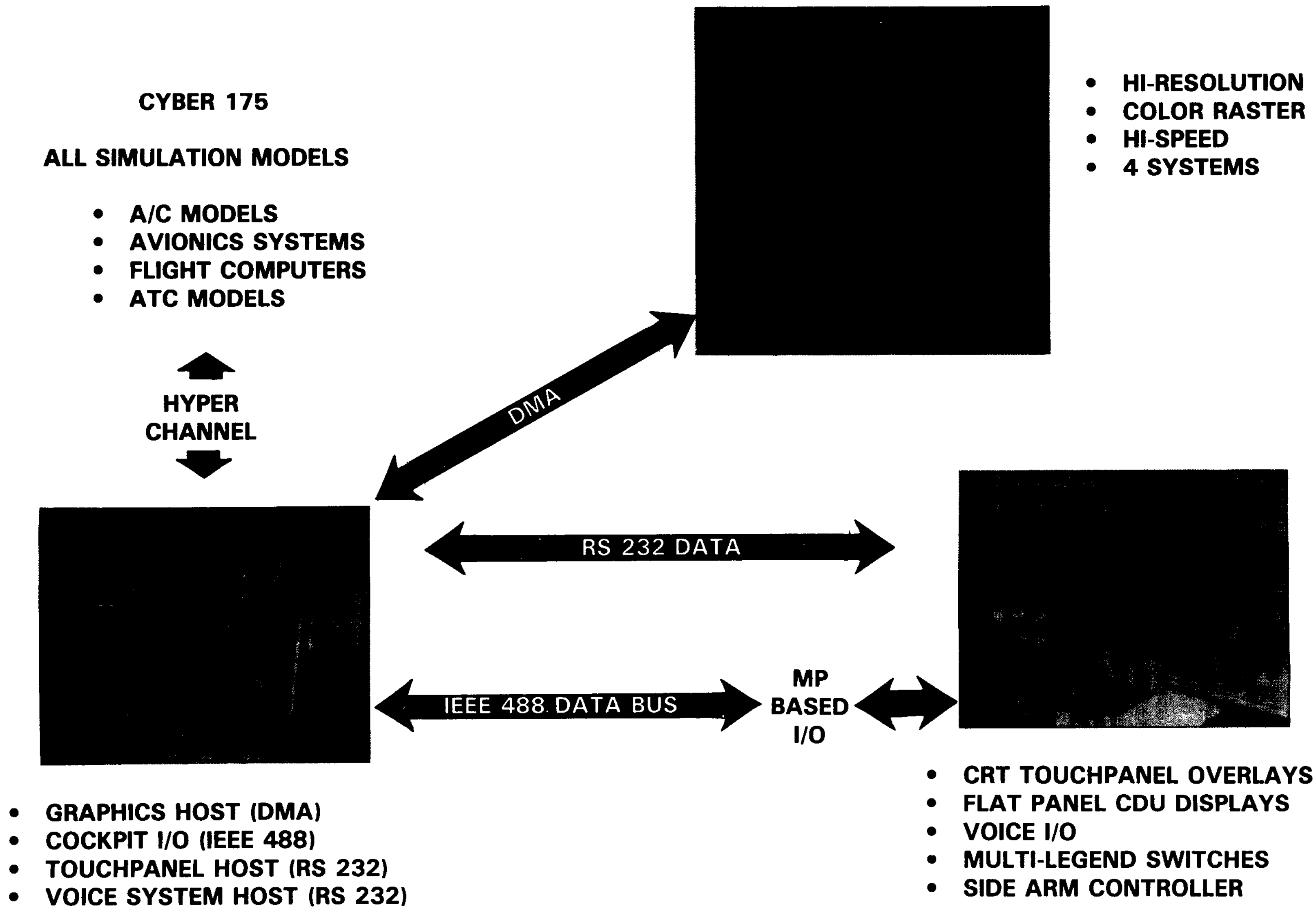
- Evaluation of flight management techniques in terminal area
- Pilot workload studies
- Cockpit display of traffic

PLANNED IMPROVEMENTS: None.

CONSTRAINTS: No General Aviation routes yet; Denver terminal area only.

LOCAL INFORMATION CONTACT: J. A. Houck, NASA–Langley Research Center, Hampton, VA, (804) 865-2981.

# ADVANCED CONCEPTS SIMULATOR



| NASA–Langley Research Center, Hampton, VA | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1984<br>**REPLACEMENT COST:** $4M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | Lockheed, GA: Advanced Concepts Flight Simulator |
| Advanced Concepts Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Advanced all-electric twin-engine transport<br>**No. of Crew Stations:** 2<br>**ATC:** Fully interactive in Denver terminal area.<br>**Other:** Advanced all-CRT flight deck with touch panels, voice I/O, and side stick controllers | **VISUAL:** None<br>**Field of View:** None<br>**Image Generation:** None<br>**Image Presentation:** None<br>**HOST COMPUTER SYSTEM:** Cyber 175 and VAX 11/780 computing Adage RDS 3000 Raster Graphics Systems | |

TYPICAL R&D PROGRAMS:

- Information management
- Interfaces to various automation levels
- Decision making assistance
- Weather management
- Matching future ATC operations

PLANNED IMPROVEMENTS:

- Visual system
- Motion capability

CONSTRAINTS: Limited only by power of computers and graphics equipment.

LOCAL INFORMATION CONTACT: B. R. Ashworth, NASA–Langley Research Center, Mail Stop 125B, Hampton, VA 23665, (804) 865-3874.

<table>
<tr><td rowspan="2">NASA–Johnson Space Center, Houston, TX</td><td colspan="2">GENERIC FLIGHT DECKS</td><td>COMPARABLE FACILITIES</td></tr>
<tr><td>DATE BUILT/UPGRADED: 1970's/1981<br>REPLACEMENT COST: $15M<br>OPERATIONAL STATUS: Fully operational</td><td>MOTION: None<br>Degrees of Freedom:<br>Linear Displacement:<br>g's:</td><td>NASA–JSC: SAIL/SMS except no flight hardware or GPC</td></tr>
<tr><td>Systems Engineering Simulator</td><td>SYSTEMS SIMULATED:<br>Aircraft Type(s): Space Shuttle, free-flying Shuttle payloads, and Manned Maneuvering Unit<br>No.of Crew Stations: 3<br>ATC: Forward orbiter station<br>Other: Aft orbiter station/MMU (interactive)</td><td colspan="2">VISUAL:<br>Field of View: 36° x 47° typical, 70°<br>Image Generation: CGI-Evans & Sutherland CT3, General Electric (Vintage 1964+)<br>Image Presentation: American Airlines, Ferrand: Orbiter forward station, 1 window; Orbiter aft station, 3 windows, 2 CCTV's; MMU, 1 window<br><br>HOST COMPUTER SYSTEM:<br>SEL 32/8780 (3), SEL 32/75 (5)</td></tr>
</table>

TYPICAL R&D PROGRAMS:

- Shuttle DDT&E (ascent, entry/landing, on-orbit–rendezvous, prox ops, RMS)
- Operations support–on-orbit multibody/RMS procedures development, crew training

PLANNED IMPROVEMENTS:

- Multibody Orbiter, Space Station, free-flyer simulation to support Space Station
- Visual system upgrade to provide additional eyepoints/scene fidelity

CONSTRAINTS: None.

LOCAL INFORMATION CONTACT: R. H. St. John, NASA–Johnson Space Center, Mail Stop EF3, Houston, TX 77058, (713) 483-4571.

<table>
<tr><td rowspan="4">DOD–Flight<br>Dynamics<br>Laboratory<br>Wright-Patterson<br>Air Force Base,<br>OH</td><td colspan="2">GENERIC FLIGHT DECKS</td><td>COMPARABLE FACILITIES</td></tr>
<tr><td>DATE BUILT/UPGRADED: 1970/1983</td><td rowspan="3">MOTION: Moving<br>Degrees of Freedom: 5 (no long.)<br>Linear Displacement: (ft)<br>Vert: ±1; lat: ±0.5<br>g's:</td><td rowspan="3">NASA–LaRC:<br>Visual Motion<br>Simulator</td></tr>
<tr><td>REPLACEMENT COST: $1M</td></tr>
<tr><td>OPERATIONAL STATUS: Operational</td></tr>
<tr><td rowspan="2">Flight/<br>Bomber<br>Simulator*</td><td rowspan="2">SYSTEMS SIMULATED:<br>Aircraft Type(s):<br>F-16 (only program to date is terrain following development F-16 model used because it was convenient)<br>No. of Crew Stations:<br>ATC:<br>Other:</td><td colspan="2">VISUAL: Day, Dusk, Night, Color<br>Field of View: 48°H x 36°V<br>Image Generation: Rediffusion: Solid Model Terrain Board<br>Image Presentation:<br>Manufacturer: Rediffusion<br>Type: Duoview</td></tr>
<tr><td colspan="2">HOST COMPUTER SYSTEM: Two SEL 32/77 digital computers with 256-KW memory each; two EAI Pacer 100 digital computers; two CSPI MAP 300 array processors; one EAI Model 327 Hyshare Interface; two EAI 781 analog computers; one EAI 7800 analog computer</td></tr>
</table>

TYPICAL R&D PROGRAMS:

- Development of terrain following/terrain
- Avoidance/automatic terrain following
- Control algorithms and cockpit displays

PLANNED IMPROVEMENTS: None.

CONSTRAINTS:

- Limited motion
- Limited field of view

LOCAL INFORMATION CONTACT: Paul E. Blatt, AFWAL/FIGD, Wright-Patterson Air Force Base, OH 45433, (513) 255-4690.

*Developed from FB-11 training simulator.

| DOD–AFHRL/OT, Williams Air Force Base, AZ | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1983/1985<br>**REPLACEMENT COST:** $8M<br>**OPERATIONAL STATUS:** Fully operational | **MOTION:** Fixed base<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | None |
| Fiber-Optic Helmet-Mounted Display (FOHMD) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** F-16C, AT-38<br>**No. of Crew Stations:**<br>**ATC:**<br>**Other:** | **VISUAL:** Full color<br>**Field of View:** Instantaneous 135°H x 64°V with a 25°H x 19°V high resolution inset. Both are slaved to an optical head tracking system. Total FOV: Unlimited.<br>**Image Generation:** Singer CGI (digital image generating system-Dig)<br>**Image Presentation:**<br>Manufacturer: FERRAND<br>Type: Two helmet-mounted pancake windows using four GE light valves.<br>**HOST COMPUTER SYSTEM:** SEL 32/9750, ADAGE | |

TYPICAL R&D PROGRAMS:

- Target recognition and acquisition
- High performance aircraft pilot head and eye movement studies

PLANNED IMPROVEMENTS: Addition of an eye-tracking system with eventual goal of eye-slaved imagery.

CONSTRAINTS: Limited only by power of computer.

LOCAL INFORMATION CONTACT: Dr. T. Longridge, AFHRL/OT, Williams Air Force Base, AZ 85240-6457, (602) 988-6561.

| DOD–AFHRL/OT, Williams Air Force Base, AZ | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1985<br>**REPLACEMENT COST:** $10M<br>**OPERATIONAL STATUS:** Fully operational by July 1986 | **MOTION:** Fixed-base<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | None |
| 24-Ft Diam. Limited Field of View Dome | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** F-16A with Block 10 and 15 configurations<br>**No. of Crew Stations:** 1<br>**ATC:**<br>**Other:** | **VISUAL:** Full color<br>**Field of View:** 140°H x 60°V (with a 26°H x 20°V high resolution inset); both background and inset are eye-slaved; eye movement is limited to 300°H x 140°V.<br>**Image Generation:** GE CGI with cell texturing.<br>**Image Presentation:**<br>Manufacturer: Spitz<br>Type: Dome projection using three GE light valves<br>**HOST COMPUTER SYSTEM:** SEL 32/8780 and 6750 with Sanders Graphics | |

TYPICAL R&D PROGRAMS:

- Evaluate dome technology
- Evaluate effect of scene contact on training effectiveness
- Evaluate head and eye-tracking systems

PLANNED IMPROVEMENTS:

- Upgrade image generating system to operate at a 60-Hz update rate with dual viewpoints
- Upgrade the other 6 of 10 channels of imagery for cell texturing

CONSTRAINTS: All imagery is slaved to head and eye-tracking.

LOCAL INFORMATION CONTACT: Capt. J. Duff, AFHRL/OT, Williams Air Force Base, AZ 85240-6457, (602)988-6561.

| | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| DOD–AFHRL/OT, Williams Air Force Base, AZ | **DATE BUILT/UPGRADED:** 1985<br>**REPLACEMENT COST:** $10M<br>**OPERATIONAL STATUS:** Fully operational by FY88 | **MOTION:** Fixed base<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | None |
| 24-in Diam. Full Field of View Dome | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** F-16C<br>**No. of Crew Stations:** 1<br>**ATC:**<br>**Other:** | **VISUAL:** Full color<br>**Field of View:** Full 360° FOV eye-slaved system; eight projectors–five active at any one time<br>**Image Generation:** GE CGI with cell texturing.<br>**Image Presentation:**<br>Manufacturer: Singer<br>Type: Dome projection using eight GE light valves<br>**HOST COMPUTER SYSTEM:**<br>SEL 32/8780 and 6750 with Sanders Graphics | |

TYPICAL R&D PROGRAMS: Evaluation of dome technology.

PLANNED IMPROVEMENTS:

- Upgrade image-generating system to operate at a 60-Hz update rate with dual viewpoints
- Upgrade the other 6 of 10 channels of imagery for cell texturing

CONSTRAINTS: Limited only by power of computers.

LOCAL INFORMATION CONTACT: Capt. J. Duff, AFHRL/OT, Williams Air Force Base, AZ 85240-6457, (602) 988-6561.

| DOD–AFHRL/ OT, Williams Air Force Base, AZ | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1985<br>**REPLACEMENT COST:** $7M<br>**OPERATIONAL STATUS:** Fully operational in September 1985 | **MOTION:** Fixed base<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | None |
| LANTIRN Low Altitude Night Terrain Infrared Navigation | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** F-16C<br>**No. of Crew Stations:** 1<br>**ATC:**<br>**Other:** | **VISUAL:** Two separate full-color systems<br>**Field of View:** (1) FLIR (forward-looking infrared radar) has a 20° x 2° FOV used for the maverick missile, a 10° x 10° used for targeting radar, and a 28°H x 30°V used for the HUD. (2) 300°H x 180° out the window CGI.<br>**Image Generation:**<br>Manufacturer: GE<br>Type: (1) Computer-generated electro-optical viewing system. (2) Computer-generated imagery with cell texturing.<br>**HOST COMPUTER SYSTEM:**<br>SEL 32/8780 and 6750 with Sanders graphics | |

TYPICAL R&D PROGRAMS:

- Syllabus development
- Workload studies
- IOS design
- Sensor-based night-attack research

PLANNED IMPROVEMENTS:

- Upgrade IOS for performance measurement
- Integrate AVTS (Advanced Visual Technology System)

CONSTRAINTS: Limited only by power of computer and graphics system.

LOCAL INFORMATION CONTACT: Ms. R. Brooks, AFHRL/OT, Williams Air Force Base, AZ 85240-6457, (602) 988-6561.

| Bell Helicopter, Fort Worth, TX | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1983<br>**REPLACEMENT COST:** $2.5M<br>**OPERATIONAL STATUS:** Fully operational | **MOTION:** Fixed-base<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | Boeing Vertol, PA: Piloted Flight Simulation Facility |
| Engineering Interactive Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Tilt rotor aircraft (XV15, JVX, LHX), general helicopters (AH1, UH1, M222, etc.)<br>**No. of Crew Stations:** 1<br>**ATC:** Battlefield management<br>**Other:** 1553 Bus I/O to actual vehicle digital avionics: digital SCAS, digital fuel control, and control loaders | **VISUAL:**<br>**Field of View:** 180° x 35° (aggregate) Four channels<br>**Image Generation:** Vital IV with data-base control and minimal surface "texturing" for NOE flight<br>**Image Presentation:** Beam splitters and infinity optics<br>**HOST COMPUTER SYSTEM:**<br>VAX 11/780 + AD10 | |

TYPICAL R&D PROGRAMS:

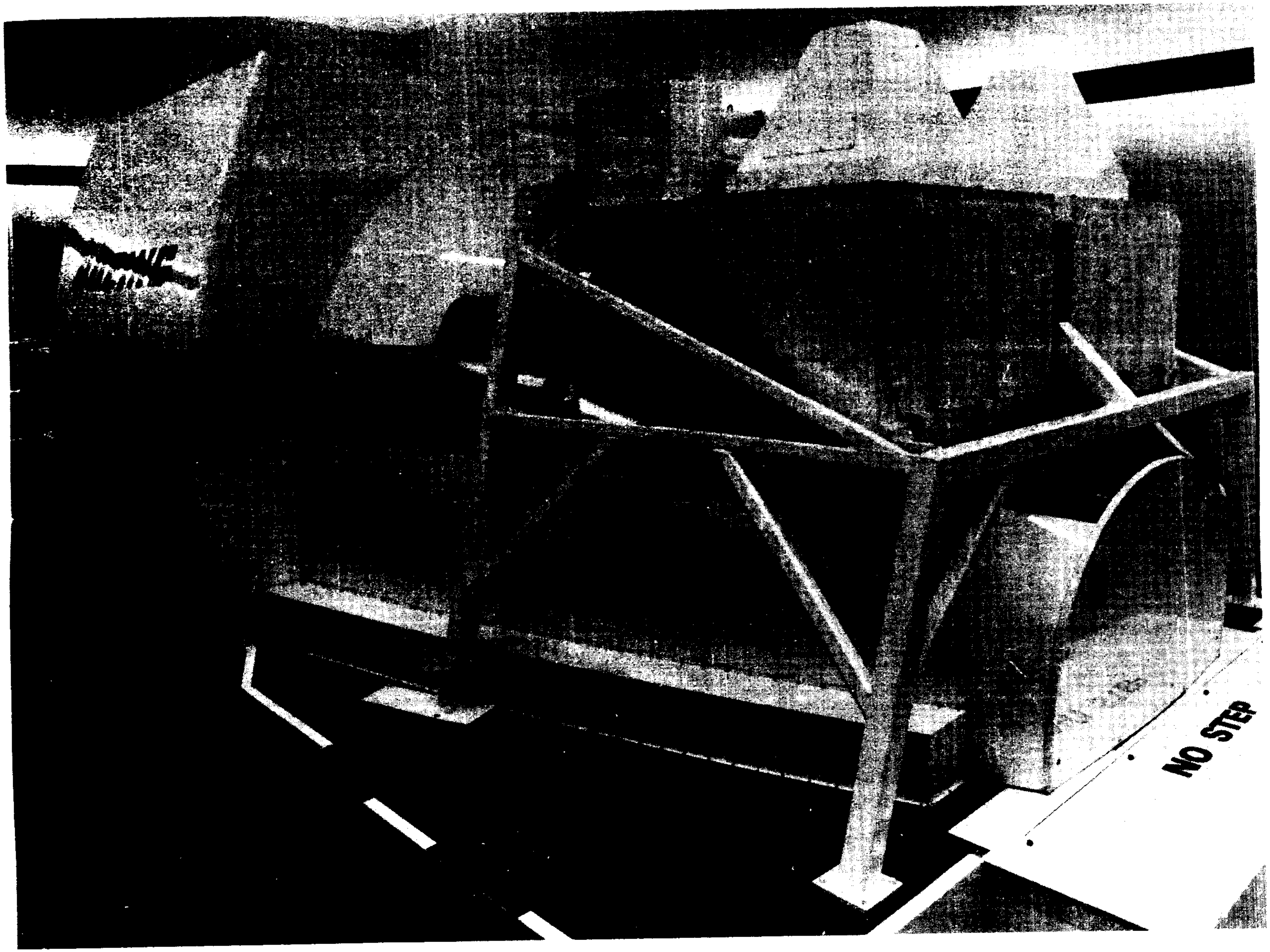
- Control law development and evaluation
- Cockpit environment design
- Display symbology design and evaluation
- Digital avionics evaluation
- Battlefield mission evaluation

PLANNED IMPROVEMENTS (1985):

- Upgrade VAX 11/780 to VAX 8600
- Upgrade AD10 to floating-point processor for Blade Element Model
- Upgrade Vital IV to five channels for sensor simulation

CONSTRAINTS: None.

LOCAL INFORMATION CONTACT: L. M. Landry, Jr., Dept. 87, Bell Helicopter Textron, P.O. Box 482, Ft. Worth, TX 76101, (817) 280-2872.


NO STEP

| The Boeing Company, Seattle, WA | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1980<br>**REPLACEMENT COST:** $5.9M<br>**OPERATIONAL STATUS:** 2 shifts per day | **MOTION:** Moving<br>**Degrees of Freedom:** 3 (vert, pitch, roll)<br>**Linear Displacement:** (in)<br>Vert: ±10<br>**g's:** 0.5 | NASA–ARC: 727 Flight Simulator |
| Flight Systems Laboratory<br><br>Multipurpose Cab | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** 707, 727, 737, 747<br><br>**No. of Crew Stations:** 2 (pilot and copilot)<br><br>**ATC:** Yes (intercom)<br><br>**Other:** Quick change capability for instruments and throttle stand, CRT displays, sound | **VISUAL:** Day, Dusk, Night, Color<br>**Field of View:** Pilot/copilot–47.4°H, 35.1°V<br><br>**Image Generation:** Pilot side window: 40.7°H, 32.5°V<br>Evans & Sutherland: CT5-CGI<br><br>**Image Presentation:**<br>Manufacturer: Evans & Sutherland<br>Type: CGI–Beamsplitter/mirror<br><br>**HOST COMPUTER SYSTEM:**<br>Harris H800 +(2) Harris Slash 6 front-end processors | |

TYPICAL R&D PROGRAMS:

- Stability and control assessment
- Flying qualities assessment
- Instrument/display development
- Pilot evaluations
- Incident investigation
- Certification

PLANNED IMPROVEMENTS: Ongoing changes as required by programs.

CONSTRAINTS: Two vision viewpoints shared between this cab and two others by scheduling.

LOCAL INFORMATION CONTACT: C. E. Phillips, Boeing Computer Services Company, Mail Stop 66-22, P.O. Box 24346, Seattle, WA 98124, (206) 237-7872.

| Boeing Vertol Company, Philadelphia, PA | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 6-75/in progress<br>**REPLACEMENT COST:** $3M<br>**OPERATIONAL STATUS:** Fully operational | **MOTION:**<br>**Degrees of Freedom:** 6<br>**Linear Displacement:** ±2.5 in<br>**Angular Accel:** 4–7 rad/sec$^2$<br>**g's:** X = ±1.5g; Y = ±0.62g; Z = ±0.62g | Bell Helicopter: Full-Mission Simulator System |
| Engineering Flight Simulator Facility | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Helicopters/VSTOL: tandem rotor, tilt rotor, and single rotor<br>**No. of Crew Stations:** 2<br>**ATC:** 1 motion base/collimated<br>**Other:** 1 fixed-base/noncollimated<br>**Targeting:** Air to ground with IHADSS system | **VISUAL:**<br>**Field of View:** 125°H, 74°V; 38° x 28.5° windows; 10° window posts<br>**Image Generation:** Multiwindow B/W CCTV optical probe with terrain board for out-of-window displays and raster scan symbol generator<br>**Image Presentation:** Collimated and noncollimated four-window CRT displays and single-channel helmet-mounted sight/display (IHADSS)<br>**HOST COMPUTER SYSTEM:**<br>Dual Perkin-Elmer 3200 MPS Computer Systems | |

TYPICAL R&D PROGRAMS:

- Helicopter flight control law development
- SAS and AFCS/FCS development
- Work-load analysis (human factors)
- Advanced cockpit management systems
- Visual display development
- A/C flight control integration, C/O (ADOCS)
- A/C avionics system integration

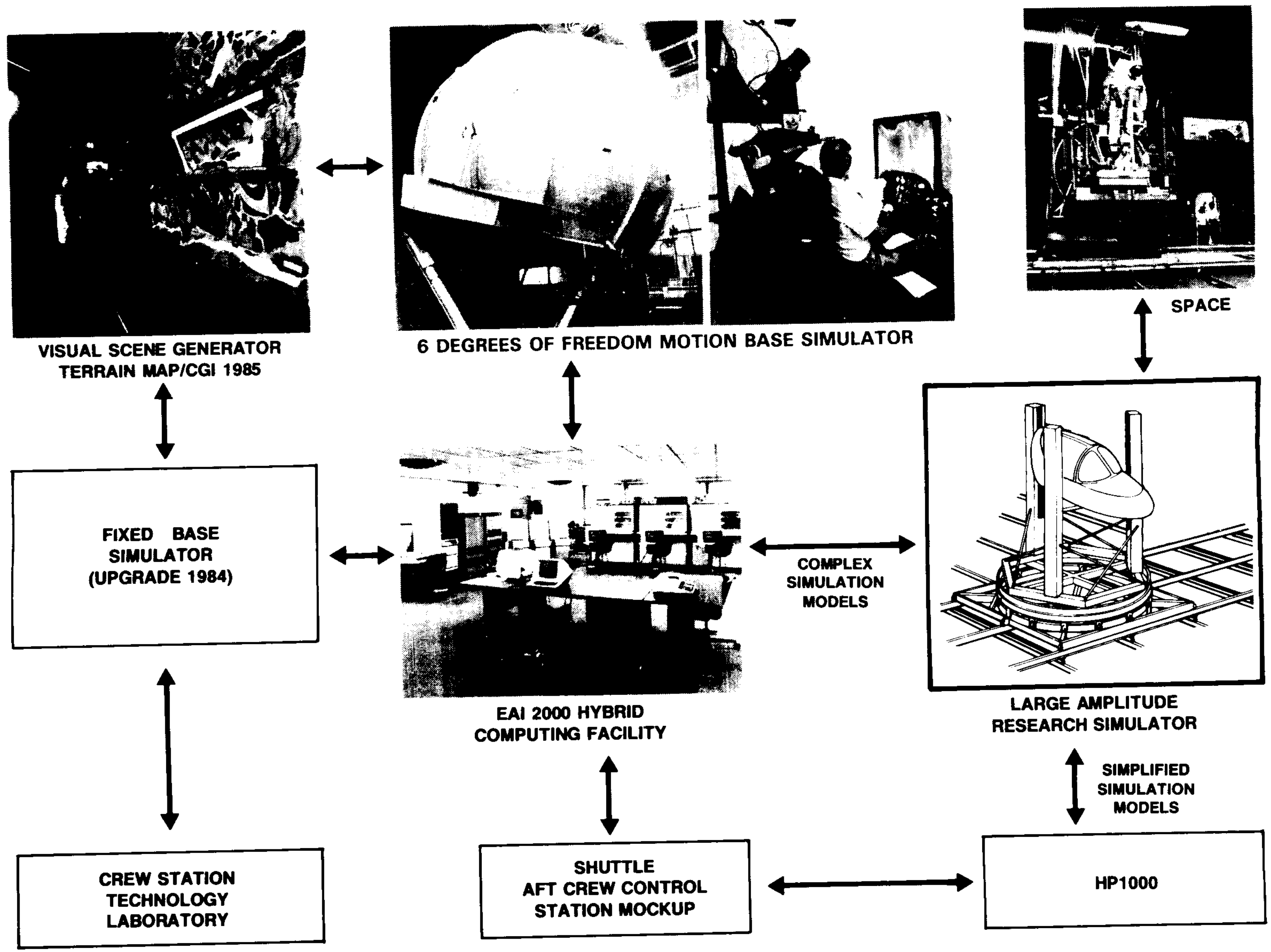
PLANNED IMPROVEMENTS:

- Computer-generated image visual system
- Large displacement motion base
- New facility building expansion
- Two interchangeable simulator cabs
- Air-to-air combat capability

CONSTRAINTS: One visual eye point (point of view).

LOCAL INFORMATION CONTACT: T. S. Garnett, Flying Qualities Flight Simulation Lab., Boeing Vertol Company, P.O. Box 16858 – Mail Stop P38-31, Philadelphia, PA 19142, (215) 522-3354.

## GRUMMAN AEROSPACE AERONAUTICAL AND SPACE R&D SIMULATION COMPLEX
## ELECTRONIC DEVELOPMENT CENTER



<table>
<tr><td rowspan="4">Grumman<br>Aerospace,<br>Bethpage, NY</td><td colspan="2">GENERIC FLIGHT DECKS</td><td>COMPARABLE FACILITIES</td></tr>
<tr><td>DATE BUILT/UPGRADED: 1980/1983</td><td rowspan="3">MOTION: Moving<br>Degrees of Freedom: 6<br>Linear Displacement: (in)<br>Vert: ±70; long: ±85; lat: ±76<br>g's: ±1.0</td><td rowspan="3">NASA–LaRC:<br>Visual Motion<br>Simulator</td></tr>
<tr><td>REPLACEMENT COST: $5M</td></tr>
<tr><td>OPERATIONAL STATUS: 6 days per week</td></tr>
<tr><td rowspan="2">Six Degrees of<br>Freedom Motion<br>Base Simulator</td><td rowspan="2">SYSTEMS SIMULATED:<br>Aircraft Type(s): X-29A, F-14, A-6<br><br>No. of Crew Stations: 2<br>(1 single pilot, 1 tandem pilot/MCO)<br><br>ATC: No<br><br>Other: Readily interchangeable instrument panels; three-axis force-feel controller</td><td colspan="2">VISUAL: Day, Color<br>Field of View: 70° model board; 240° target tracking<br><br>Image Generation: Grumman<br>Model board, optical probe, color TV, Hi Resolution TV, and moving target model<br>Image Presentation: Manufacturer: Grumman<br>Type: TV monitor/Fresnel lens; target TV projector and wide FOV horizon projector on 19-ft dia. spherical screen</td></tr>
<tr><td colspan="2">HOST COMPUTER SYSTEM: EAI 2000 Hybrid Computing System (two independent systems)</td></tr>
</table>

TYPICAL R&D PROGRAMS:

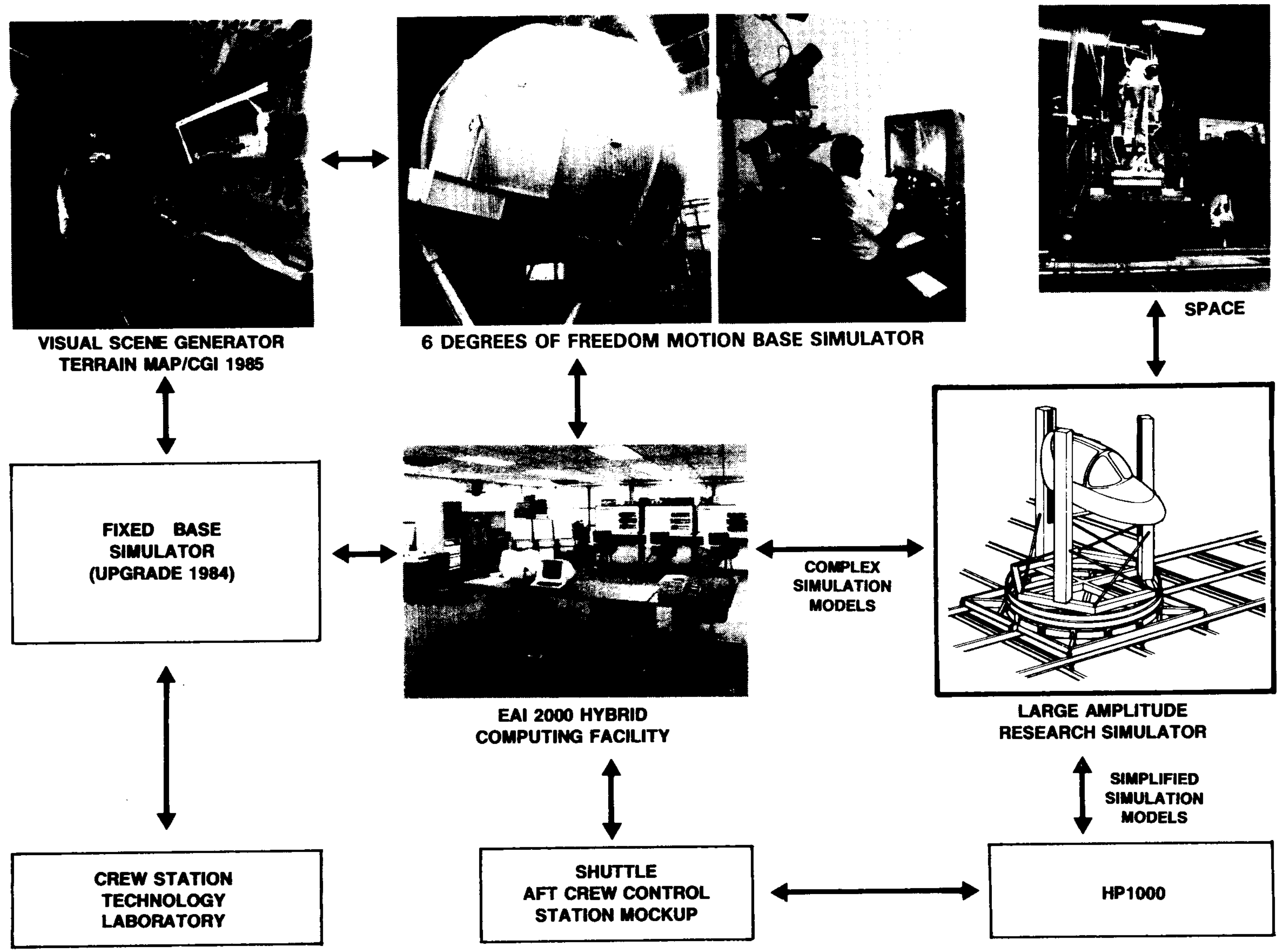
- Control system evaluation
- Handling qualities
- Failure analysis
- Weapon system evaluation
- Departure characteristics
- Man/machine interface
- Advanced design concepts

PLANNED IMPROVEMENTS: Computer image generation visual system.

CONSTRAINTS: No constraints within the operational capability.

LOCAL INFORMATION CONTACT: Thomas Garner, Grumman Aerospace Corp., Mail Station C03-14, Bethpage, NY 11714, (516) 575-5626.

## GRUMMAN AEROSPACE AERONAUTICAL AND SPACE R&D SIMULATION COMPLEX ELECTRONIC DEVELOPMENT CENTER



| Grumman Aerospace, Bethpage, NY | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** Upgraded 1984<br>**REPLACEMENT COST:** $3M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | Hughes Aircraft: Advanced Flight Simulator |
| Fixed-Base Simulator<br><br>Crew Station Technology Lab | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** F-14, A-6, VSTOL<br>**No. of Crew Stations:** 2 (1 pilot, 1 copilot)<br>**ATC:** No<br>**Other:** Standard instrument panel CRT crew station with touch panel, voice I/O, color displays, programmable switches | **VISUAL:**<br>**Field of View:** 70° model board<br>**Image Generation:** Grumman Aerospace Model board<br>**Image Presentation:**<br>Manufacturer: Grumman<br>Type: Projection 24-ft dia. partial dome<br>**HOST COMPUTER SYSTEM:** SEL 32/8750 and IPU's and peripherals Sanders Graphics 7 & 8, Gaertner DDS 480S AGP Color Graphics System | |

TYPICAL R&D PROGRAMS:

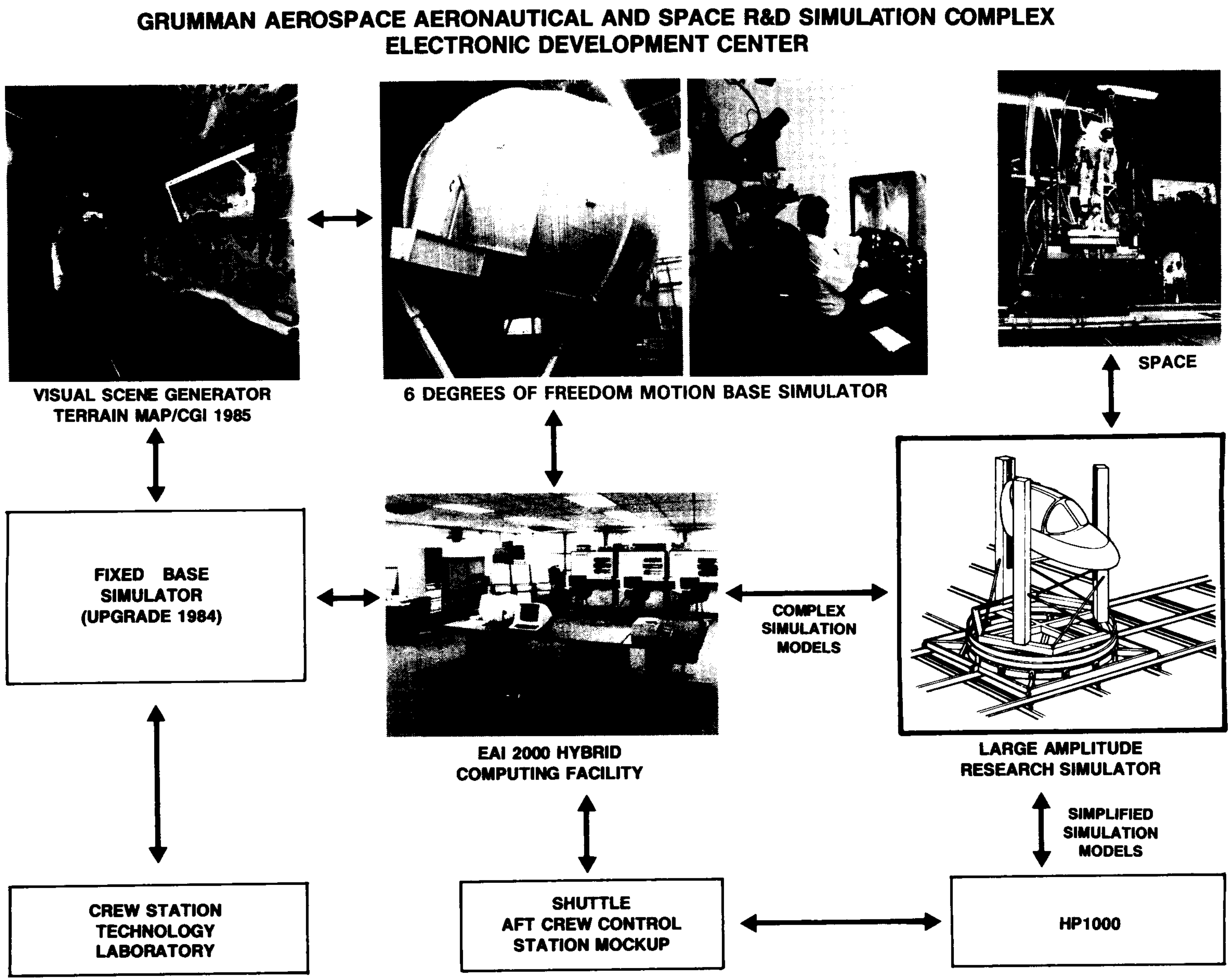
- Handling qualities
- Three-dimensional pictorial display formats
- Use of color in flight and tactical displays
- Role of voice technology in flight crew stations

PLANNED IMPROVEMENTS:

- Visual system
- Cockpit

CONSTRAINTS: Computers and graphics equipment.

LOCAL INFORMATION CONTACTS: H. Sherman, Grumman Aerospace Corp., Mail Station C04-14, Bethpage, NY 11714, (516) 575-7784; T. Garner, Grumman Aerospace Corp., Mail Station C03-14, Bethpage, NY 11714, (516) 575-5626.


GRUMMAN AEROSPACE AERONAUTICAL AND SPACE R&D SIMULATION COMPLEX
ELECTRONIC DEVELOPMENT CENTER
VISUAL SCENE GENERATOR
TERRAIN MAP/CGI 1985
6 DEGREES OF FREEDOM MOTION BASE SIMULATOR
SPACE
FIXED BASE
SIMULATOR
(UPGRADE 1984)
EAI 2000 HYBRID
COMPUTING FACILITY
COMPLEX
SIMULATION
MODELS
LARGE AMPLITUDE
RESEARCH SIMULATOR
SIMPLIFIED
SIMULATION
MODELS
CREW STATION
TECHNOLOGY
LABORATORY
SHUTTLE
AFT CREW CONTROL
STATION MOCKUP
HP1000

<table>
<tr><td rowspan="4">Grumman Aerospace, Bethpage, NY</td><td colspan="2">GENERIC FLIGHT DECKS</td><td>COMPARABLE FACILITIES</td></tr>
<tr><td>DATE BUILT/UPGRADED: 1981/continuous upgrade</td><td rowspan="3">MOTION: Moving<br>Degrees of Freedom: 6<br>Linear Displacement: (ft)<br>Vert: 10; long: 40; lat: 35<br>g's: 1/2 all axes</td><td rowspan="3">NASA–ARC: 6 DOF Simulator</td></tr>
<tr><td>REPLACEMENT COST: $1M</td></tr>
<tr><td>OPERATIONAL STATUS: 1 shift per day</td></tr>
<tr><td rowspan="2">Large Amplitude Research Simulator (LARS)</td><td rowspan="2">SYSTEMS SIMULATED:<br>Aircraft Type(s): VTOL (hover mode)<br>No.of Crew Stations: 1<br>ATC: No<br>Other: Manned remote work stations, remote manipulator systems, and small free-flyers (space)</td><td colspan="2">VISUAL:<br>Field of View: Out of window (hover mode)<br>Image Generation: None<br>Image Presentation: None</td></tr>
<tr><td colspan="2">HOST COMPUTER SYSTEM: Hewlett Packard 1000 System (F-Computer and peripherals); EAI 2000 Hybrid Computing Facility</td></tr>
</table>

TYPICAL R&D PROGRAMS:

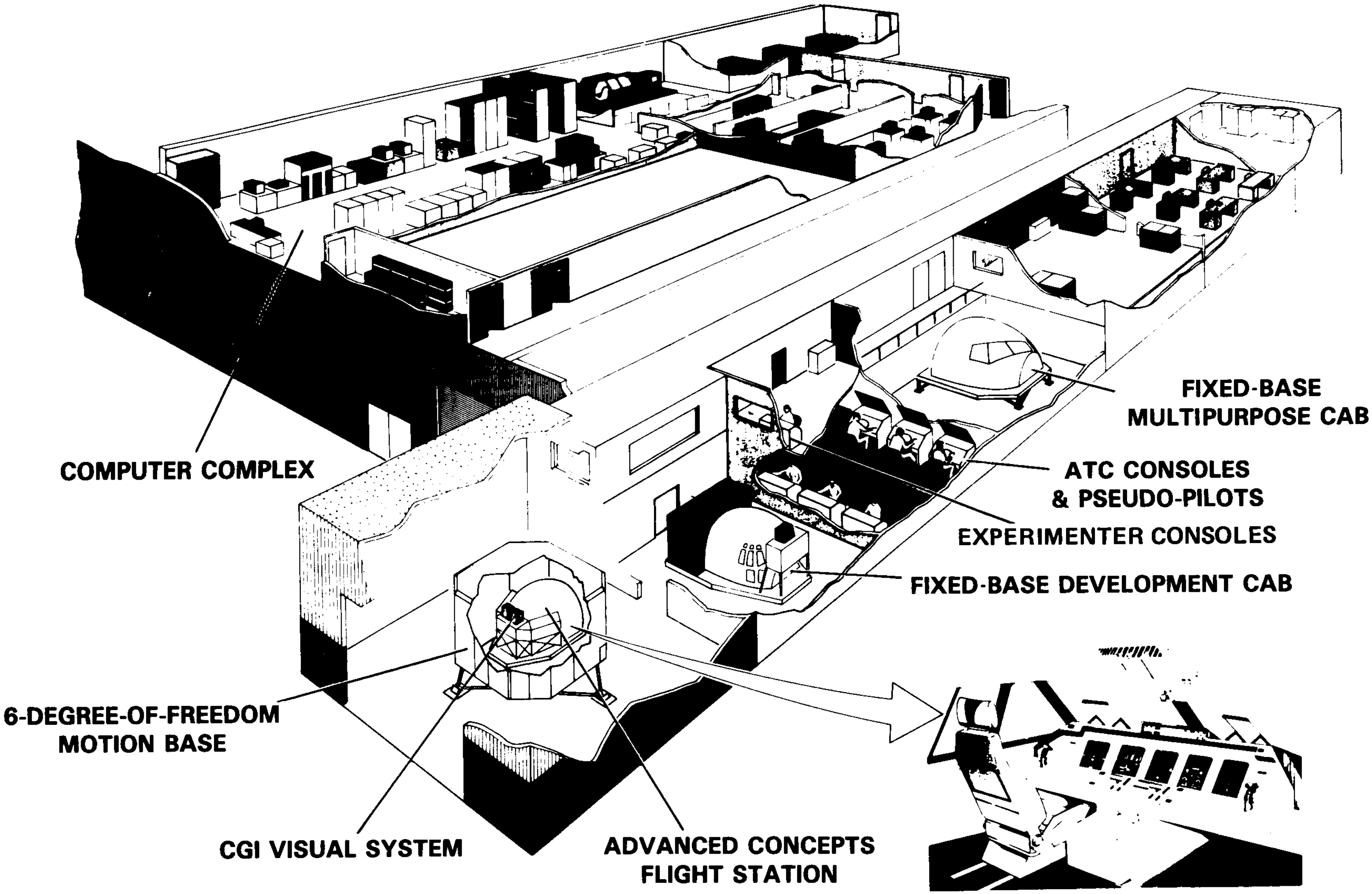
- Research in V/STOL handling qualities requirements
- VTOL flight-control development
- Small space-vehicle command/control development
- Astronaut familiarization with Shuttle-related activities

PLANNED IMPROVEMENTS:

- Expansion of operating area to facilitate interchange of programs
- Transition to all digital control and measurement
- Extension of system frequency responses

CONSTRAINTS: Physical limitations of system only.

LOCAL INFORMATION CONTACT: Harry T. Breul, R&D Center, Grumman Aerospace Corporation, Mail Station A8-35, Bethpage, NY 11714, (516) 575-1971.


FIXED-BASE
MULTIPURPOSE CAB
COMPUTER COMPLEX
ATC CONSOLES
& PSEUDO-PILOTS
EXPERIMENTER CONSOLES
FIXED-BASE DEVELOPMENT CAB
6-DEGREE-OF-FREEDOM
MOTION BASE
CGI VISUAL SYSTEM
ADVANCED CONCEPTS
FLIGHT STATION

| | | | |
|---|---|---|---|
| Lockheed Georgia Co., Marietta, GA | **GENERIC FLIGHT DECKS** | | **COMPARABLE FACILITIES** |
| | **DATE BUILT/UPGRADED:** 1984<br>**REPLACEMENT COST:** $6M<br>**OPERATIONAL STATUS:** Operational | **MOTION:** 1 Moving; 3 Fixed<br>**Degrees of Freedom:** 6<br>**Linear Displacement:** (in)<br>Vert: ±33; long: ±48; lat: ±48<br>**g's:** 0.8, 0.6, 0.6 | NASA–ARC:<br>Advanced Concepts Flight Simulator |
| Man-Vehicle Systems Laboratory | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>Advanced concepts transport, assault transport (C-130, C-5)<br>**No.of Crew Stations:** 4<br>(1–2 crew each)<br>**ATC:** Yes<br>**Other:** Advanced all-CRT flight deck with touch panels, voice I/O, and side-stick controllers | **VISUAL:** Day, Dusk, Night, Color<br>**Field of View:** 36° x 48°<br>**Image Generation:** Dalto; Rediffusion Model Board and E&S SP-2 CGI<br>**Image Presentation:**<br>Manufacturer: American Airlines<br>Type: Spherical mirror/beamsplitter<br>**HOST COMPUTER SYSTEM:**<br>Two VAX 11/780, one SEL 32/77, one SEL 32/87, five TI 980 | |

TYPICAL R&D PROGRAMS:

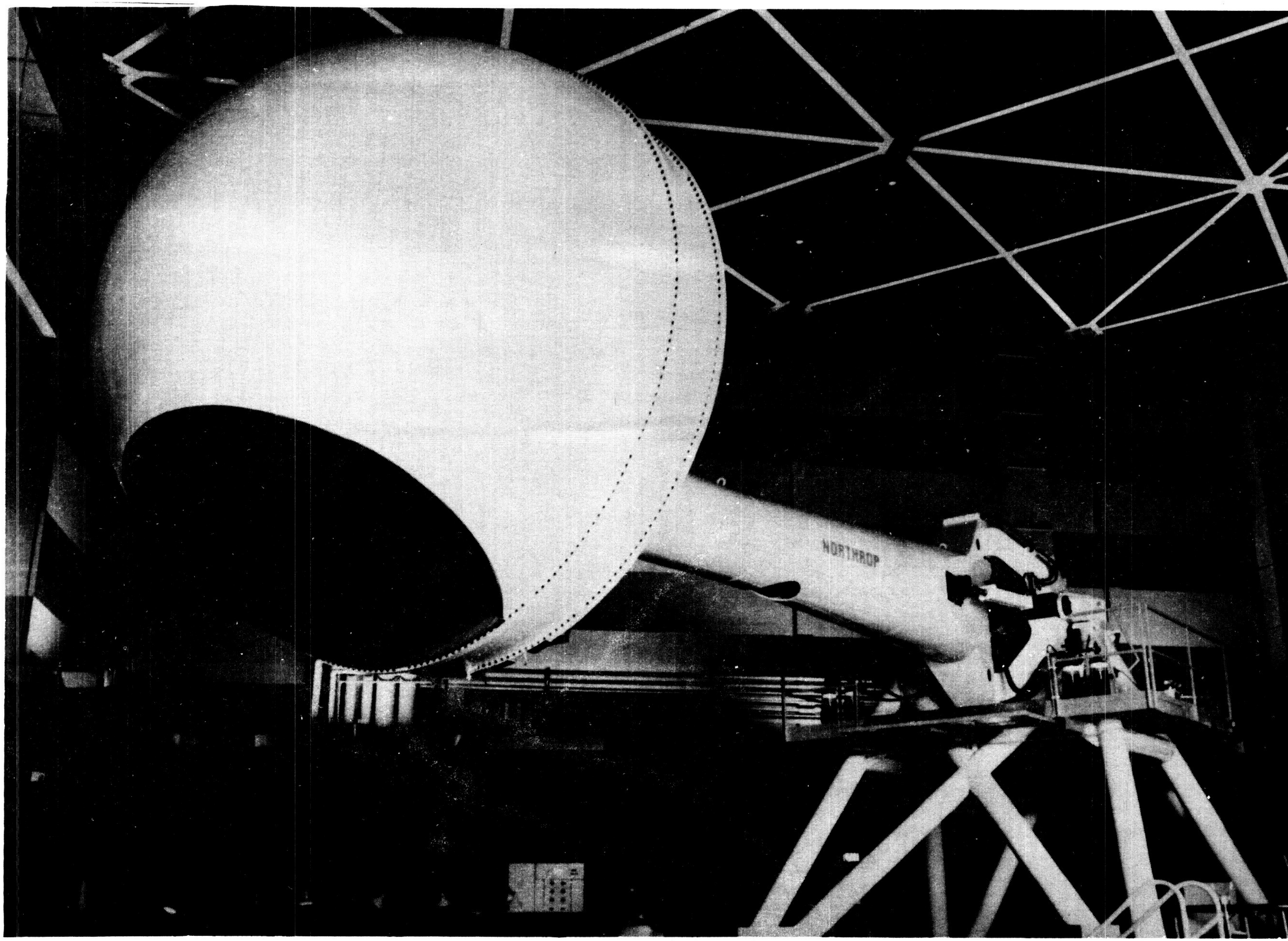
- Aircraft handling qualities development
- Aircraft flight control system design
- Hardware integration/verification
- Avionic software development/verification
- Man/machine interface
- Integrated controls and displays

PLANNED IMPROVEMENTS:

- Wide field-of-view visual system
- Increased capability host computer

CONSTRAINTS: With four cockpits, two visual systems, and one motion system, it is necessary to swap equipment and flight stations as program requirements dictate.

LOCAL INFORMATION CONTACT: C. P. Moore, Manager, Department 72-36, Zone 410, Lockheed Georgia Company, Marietta, GA 30063, (404) 424-5642.


NORTHROP

| Northrop Aircraft Division, Hawthorne, CA | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1971<br>**REPLACEMENT COST:** N/A<br>**OPERATIONAL STATUS:** Operational | **MOTION:** beam type<br>**Degrees of Freedom:** 5<br>**Linear Displacement:**<br>Beam ±10-ft vertical and lateral cockpit<br>±25° pitch, roll, yaw<br>**g's:** 2.5 | DOD–Wright Patterson: LAMARS |
| Large Amplitude Simulator (LAS) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** All types of tactical aircraft<br>**No. of Crew Stations:** 1<br>**ATC:**<br>**Other:** G-suit | **VISUAL:** Ground Scene<br>**Field of View:** 50° x 50°<br>**Image Generation:** Singer Link DIG<br>**Image Presentation:** Dome<br>**HOST COMPUTER SYSTEM:**<br>Five Harris Slash 4's | Target<br>15° slewable<br>Camera Model System<br>Dome |

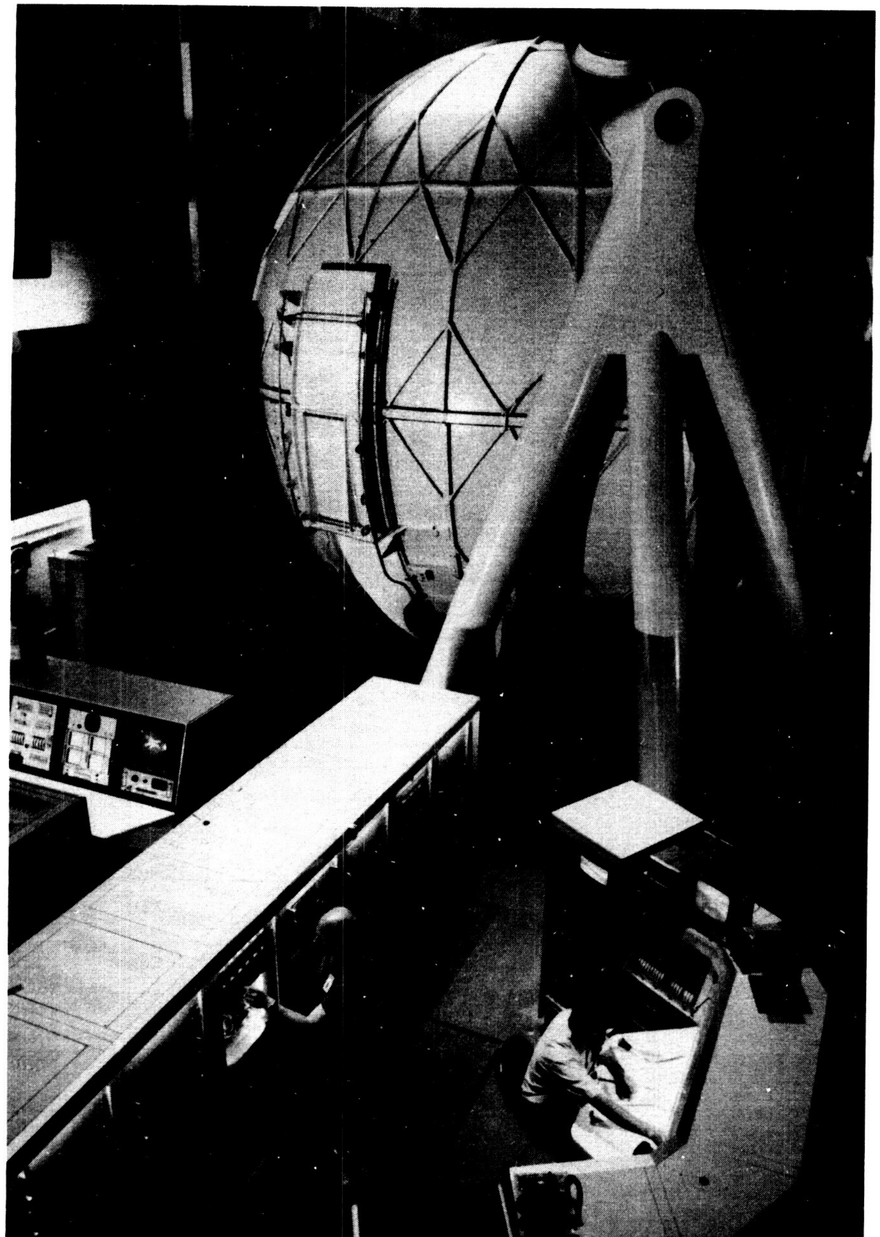
TYPICAL R&D PROGRAMS:

- Flight control development
- Handling qualities studies
- Weapons systems evaluations
- Air combat simulation

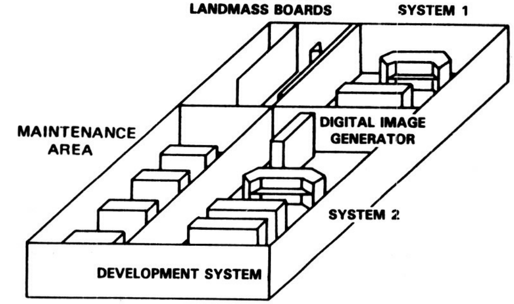
PLANNED IMPROVEMENTS: None.

CONSTRAINTS: None.

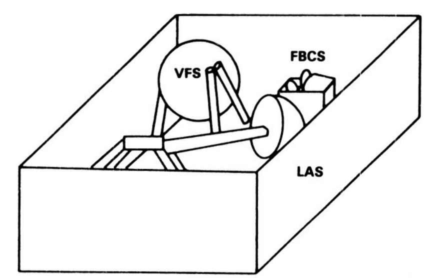
LOCAL INFORMATION CONTACT: M. L. Flax, Northrop Corporation, One Northrop Avenue, 3845/64, Hawthorne, CA 90250, (213) 970-4037.



# NORTHROP FLIGHT SIMULATION LABORATORY




COMPUTER FACILITY




CREW STATION FACILITY

| Northrop Aircraft Division, Hawthorne, CA | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1980<br>**REPLACEMENT COST:** N/A<br>**OPERATIONAL STATUS:** Operational | **MOTION:** None<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** None | McDonnell Douglas, MO: MACS |
| Visual Flight Simulator (VFS) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** All types of tactical aircraft<br>**No.of Crew Stations:** 1<br>**ATC:**<br>**Other:** G-suit | **VISUAL:** Ground Scene<br>**Field of View:** 150° x 50°<br>**Image Generation:** Singer Link DIG<br>**Image Presentation:** Dome<br>**HOST COMPUTER SYSTEM:**<br>Five Harris Slash 4's | Target<br>15° slewable<br>Camera Model System<br>Dome |

TYPICAL R&D PROGRAMS:

- Avionics integration
- Crew station evaluation
- Human factors studies
- Weapon systems evaluations
- Full mission simulation
- Air combat simulation

PLANNED IMPROVEMENTS: None.

CONSTRAINTS: None.

LOCAL INFORMATION CONTACT: M. L. Flax, Northrop Corporation, One Northrop Avenue, 3845/64, Hawthorne, CA 90250, (213) 970-4037.

| Sikorsky Aircraft, Stratford, CT | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** July 1984<br>**REPLACEMENT COST:** $4.5M<br>**OPERATIONAL STATUS:** Fully operational | **MOTION:** Fixed base<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | Bell Helicopter: Full-Mission Simulator System |
| Fixed-Base Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Variety of rotorcraft<br>**No. of Crew Stations:** 1 or 2<br>**ATC:**<br>**Other:** Conventional and sidearm controllers, collision detection, height above terrain, sensor channel, and real-time sound system | **VISUAL:**<br>**Field of View:** 140°H, 60°V for three screens relocatable chin window of 45°H, 60°V<br>**Image Generation:** Rediffusion Simulation computer-generated imagery/Evans & Sutherland Modified SP3T Triad.<br>**Image Presentation:** Three screens and one relocatable chin window screen<br>**HOST COMPUTER SYSTEM:**<br>DEC PDP 10 and PDP 11 | |

TYPICAL R&D PROGRAMS:

- Systems integration
- Rotorcraft handling qualities and control systems research
- Human factors cockpit development studies
- Tactical situation studies
- NOE flight evaluations

PLANNED IMPROVEMENTS: None.

CONSTRAINTS: Limited only by capabilities of visual computers.

LOCAL INFORMATION CONTACT: Ray Thornberg, Sikorsky Aircraft, Simulation Software, Main Street, Stratford, CT 06601, (203) 386-4470.

| Sikorsky Aircraft, Stratford, CT | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1985–1986<br>**REPLACEMENT COST:** $11M<br>**OPERATIONAL STATUS:** Operational April 1986 | **MOTION:**<br>**Degrees of Freedom:** 6<br>**Linear Displacement:** (in) Vert: +32, -39; lat: +45, -45; long: +43, -43<br>**Approx. Angular Displacements:** ±25°<br>**g's:** Peak Acc 1.1g; Onset Acc. ±5g/sec | None |
| Engineering Development Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):** Variety of rotorcraft<br>**No. of Crew Stations:** 1 or 2<br>**ATC:**<br>**Other:** Conventional and sidearm controllers, collision detection, height above terrain, and sensor channel | **VISUAL:**<br>**Field of View:** 180°H, +20 to -60°V<br>**Image Generation:** Computer-generated imagery by General Electric's Compu-Scene IV<br>**Image Presentation:** 20-ft aluminum dome<br>**HOST COMPUTER SYSTEM:** One DEC PDP 10, two SEL's | |

TYPICAL R&D PROGRAMS:

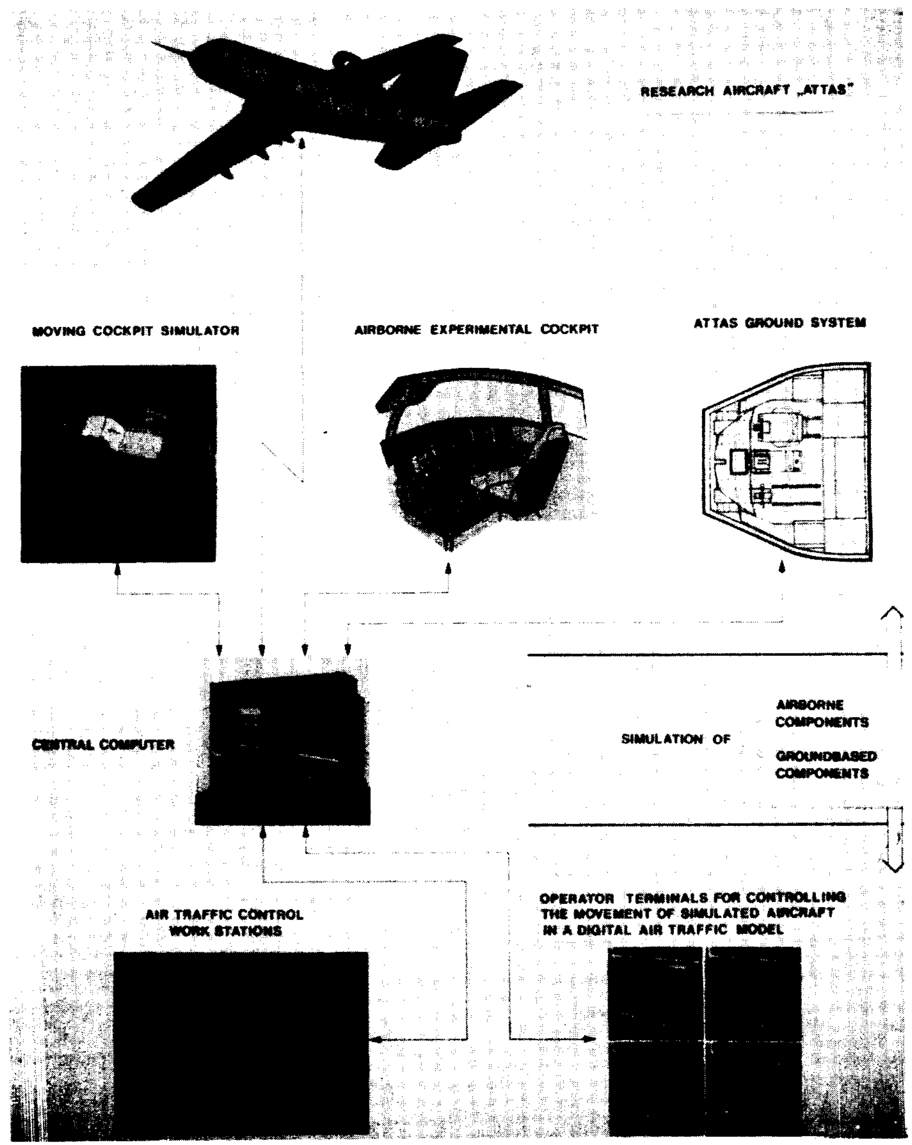
- Systems integration
- Rotorcraft handling qualities and control systems research
- Human factors cockpit development studies
- Tactical situation studies
- NOE flight evaluations

PLANNED IMPROVEMENTS: Eye/head tracker.

CONSTRAINTS: Limited only by capabilities of visual system.

LOCAL INFORMATION CONTACT: Ray Thornberg, Sikorsky Aircraft, Simulation Software, Main Street, Stratford, CT 06601, (203) 386-4470.

# ATMOS AIR TRAFFIC MANAGEMENT AND OPERATIONS SIMULATOR



| Germany–DFVLR | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1982/1984<br>**REPLACEMENT COST:** $1M<br>**OPERATIONAL STATUS:*** ATC: 1983<br>AEC: 1985 | **MOTION:** Fixed<br>**Degrees of Freedom:**<br>**Linear Displacement:**<br>**g's:** | NASA–LaRC:<br>MOTAS |
| Air Traffic Management and Operations Simulator (ATMOS) | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>Advanced FBW transport<br>**No.of Crew Stations:** 2<br>(1 alternative)<br>**ATC:** Yes<br>**Other:** Full real-time simulation 1400 x 1400 nm area; advanced aft flight deck, and variably configured displays and controls | **VISUAL:** None<br>**Field of View:**<br>**Image Generation:**<br>**Image Presentation:**<br>**HOST COMPUTER SYSTEM:** VAX 11/750, PDP 11/50 (dual), PDP 11/34, several LSI-Micros; Evans & Sutherland, PS2 graphics system | |

TYPICAL R&D PROGRAMS: Integration of Air Traffic Management and Flight Management Systems

- Airborne component
  - Flight management systems
  - Structure, information management/presentation
  - Air/ground communications by data link
  - Cooperative interaction with advanced ATC systems
  - In-flight validation onboard ATTAS research aircraft
- ATC component
  - Air traffic management systems
  - Operations in full-scale advanced scenarios (50 simulated A/C and "live" ATTAS research aircraft)
  - Benefits of EMS capabilities for ATC planning and procedures
  - Optimum interaction controller/automated ATC

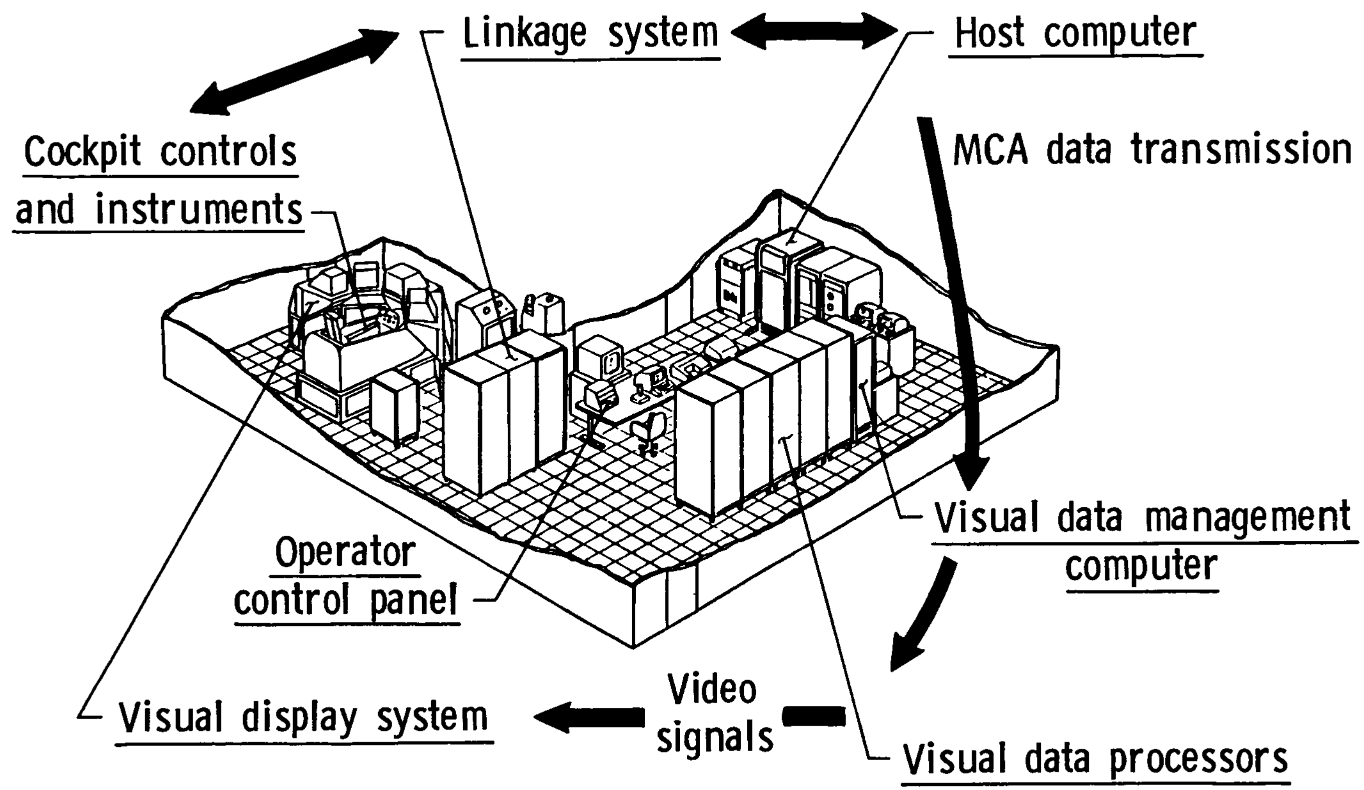
PLANNED IMPROVEMENTS:

CONSTRAINTS:

LOCAL INFORMATION CONTACT: J. Thomas, DFVLR, Institute for Flight Guidance, P.O. Box 3267, D-3300 Braushweig/FGR, phone: 0532-3952501.

*AEC: Airborne Experimental Cockpit; ATTAS: Advanced Technologies and Testing Aircraft System.

# GENERAL ARRANGEMENT OF SARD FLIGHT SIMULATOR



<table>
<tr><td rowspan="4">Japan–Kawasaki Heavy Industries Aircraft Engineering Department</td><td colspan="2">GENERIC FLIGHT DECKS</td><td>COMPARABLE FACILITIES</td></tr>
<tr><td>DATE BUILT/UPGRADED: 1983</td><td rowspan="3">MOTION: Fixed with buffeting system<br>Degrees of Freedom:<br>Linear Displacement:<br><br>g's:</td><td rowspan="3">Hughes Aircraft:<br>Advanced Flight Simulator</td></tr>
<tr><td>REPLACEMENT COST: $2M</td></tr>
<tr><td>OPERATIONAL STATUS: 1 shift per day</td></tr>
<tr><td rowspan="2">Simulator for Aircraft Research and Development (SARD)</td><td rowspan="2">SYSTEMS SIMULATED:<br>Aircraft Type(s):<br>Advanced fighter and trainer aircraft<br><br>No. of Crew Stations: 1<br><br>ATC:<br><br>Other:</td><td colspan="2">VISUAL: Day, Dusk, Color<br>Field of View: 44° x 35° x 4° windows (channels)<br><br>Image Generation: Mitsubishi Precision Co.<br>Computer-generated imagery<br><br>Image Presentation:<br>Manufacturer: Mitsubishi Precision Co.<br>Type: Virtual image and infinity via corrimeter mirrors</td></tr>
<tr><td colspan="2">HOST COMPUTER SYSTEM: Data General Eclipse MV/8000; Nippon Data General MP/200X2 and NOVA 4X; Sony Tektronix 4112 Pen Recorders (12ch x 2)</td></tr>
</table>

TYPICAL R&D PROGRAMS:

- Handling qualities (T/O and L/D, cruise, formation, tracking, air mobility, high AOA, etc.)
- Digital flight control systems
- HUD display systems
- Fire control systems

PLANNED IMPROVEMENTS:

- Motion cue
- General-purpose cockpit (for transport aircraft and helicopters)

CONSTRAINTS: Limited only by power of computers.

LOCAL INFORMATION CONTACT: Takashi Miyatake, Aircraft Engineering Department, Kawasaki Heavy Industries, Ltd., 1, Kawasaki-Cho, Kakamigahara-Shi, Gifu 504, Japan, phone: 0583-82-5111, ext. 3420.

| Netherlands–Netherlands Research Laboratory, Amsterdam | GENERIC FLIGHT DECKS | | COMPARABLE FACILITIES |
|---|---|---|---|
| | **DATE BUILT/UPGRADED:** 1976<br>**REPLACEMENT COST:**<br>**OPERATIONAL STATUS:** 1977 | **MOTION:** Moving<br>**Degrees of Freedom:** 4 (vert, pitch, roll, yaw)<br>**Linear Displacement:**<br>Vert.-I 0.285 meters<br>**g's:** 7.7 vert | NASA–LaRC: Visual Motion Simulator |
| Moving-Base Flight Simulator | **SYSTEMS SIMULATED:**<br>**Aircraft Type(s):**<br>Civil and military single and twin-engine aircraft<br>**No. of Crew Stations:**<br>**ATC:** No<br>**Other:** | **VISUAL:**<br>**Field of View:**<br>**Image Generation:** Terrain model viewed through closed circuit color TV; Singer Link and Miles<br>**Image Presentation:** Mark V TV monitor viewed through collimating system<br>**HOST COMPUTER SYSTEM:**<br>Perkin-Elmer Computer System | |

TYPICAL R&D PROGRAMS: The simulator will serve as a tool for studying a broad field of problems related to pilot/aircraft interactions. This comprises the following areas:

- Requirements for design and modification: Handling qualities of new designs, criteria for riding qualities, and studies of new concepts for control and display
- New operational procedures and tactics: Implementation of microwave landing system, windshear on the approach, and pilot workload
- Flight simulation technology improvement: Motion system drive laws, relation between motion and visual cues, and turbulence models

SPECIAL FEATURES: Outstanding features of this simulator are its special motion system with low acceleration noise and threshold levels and its adaptability to a variety of research studies by using to a large extent digital computing techniques in simulating different aircraft characteristics and in using different cockpits that can rapidly be exchanged.

LOCAL INFORMATION CONTACT: W. P. de Boer, Head, Stability and Control Department Flight Division, Netherlands Research Laboratory, Amsterdam, Netherlands.

# LIST OF INSTALLATION ADDRESSES

## UNITED STATES INSTALLATIONS

Allison Gas Turbine Operations
P.O. Box 894
Indianapolis, IN 46206

Arnold Engineering Development Center
Air Force Station, TN 37389

Bell Helicopter Textron
Dept. 87, GP 38
P.O. Box 482
Ft. Worth, TX 76101

The Boeing Company
P.O. Box 24346 M/S 66-22
Seattle, WA 98124

Boeing Vertol
P.O. Box 16858
Philadelphia, PA 19142

Garrett Turbine Engine Company
111 South 34th Street
P.O. Box 5217
Phoenix, AZ 85010

General Electric Company
Aircraft Engine Business Group
Cincinnati, OH 45215

General Electric Company
Business Group
1000 Western Avenue
Lynn, MA 01910

Grumman Aerospace Corporation
M/S C02
Bethpage, NY 11714

Hughes Aircraft Company
Aerospace Group
Culver City, CA

Lockheed-Georgia Company
Dept. 72-36, Zone 324
Marietta, GA 30060

The Marquardt Company
16555 Satcoy Street
Van Nuys, CA 91409

Martin Marietta Corporation
MP 75
P.O. Box 5837
Orlando, FL 32805

Massachusetts Institute of Technology
Cambridge, MA 02139

McDonnell Douglas Corporation
Dept. 251, Bldg. 105-2-A1
P.O. Box 516
St. Louis, MO 63166

National Aeronautics and Space
Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135

National Aeronautics and Space
Administration
Langley Research Center
Hampton, VA 23665

## UNITED STATES INSTALLATIONS (Continued)

National Aeronautics and Space
Administration
Ames Research Center
Moffett Field, CA 94035

National Aeronautics and Space
Administration
Lyndon B. Johnson Space Center
Houston, TX 77058

Naval Air Propulsion Center
P.O. Box 7176
Trenton, NJ 08628

Northrop Corporation
North American Aircraft Division
Mail Stop RA 03
P.O. Box 92098
Los Angeles, CA 90009

Pratt & Whitney
Aircraft Engine Division
Government Products Division
West Palm Beach, FL 33402

Pratt & Whitney
United Technologies Research Center
Silver Lane
East Hartford, CT 06108

Rockwell International Corporation
Space Division
12214 South Lakewood Blvd.
Downey, CA 90241

Sikorsky Aircraft
Control Branch
North Main Street
Stratford, CN 06602

Teledyne-CAE
Box 6971
1330 Laskey Road
Toledo, OH 43612

USAF Human Resources Laboratory
Williams AFB, AZ 85224

U.S. Army Fuels and Lubricants
Research Laboratory
Southwest Research Institute
P.O. Box 28510
San Antonio, TX 22314

Westinghouse Electric Company
Combustion Turbine Systems
Division
Waltz Mills, PA

Wright Patterson AFB
AFWAL/POT
Dayton, OH 45433

## FOREIGN INSTALLATIONS

Centre D'essais des Propulseurs
Saclay, 91406 Orsay, Cedex, France

Deutsche Forschungs-und Versuchsanstalt
fur Luft-und Raumfahrt e.V (DFVLR)
Postfach 90 60 58
5000 Koln 90

National Aerospace Laboratory
(NRL)
P.O. Box 126
1006 BM Amsterdam
Netherlands

National Gas Turbine Establishment
Pyestock, Farnborough HANTS/GU
14 OIS
United Kingdom

National Research Council of Canada (NRC)
Montreal Road
Bldg. M 13A
Ottawa, Ontario K1A0R6
Canada

Ministry of Defense
Royal Aircraft Establishment (RAE)
Farnborough Hants G0146TD
United Kingdom

FOREIGN INSTALLATIONS (Continued)

Office National D'Etudes et de Recherches
Aerospaltiales (ONERA)
29 Avenue de la Division Leclerc
92320 Chatillon
France

Rolls Royce Limited
Aerodivision Bristol
P.O. Box 3
Filton, Bristol, United Kingdom

Rolls Royce Limited
Aerodivision Division
P.O. Box 31
Derby DE2/8BJ
United Kingdom

Scientific Attache
American Embassy Japan
APO San Francisco
96503

University of Stuttgart
Pfaffenwaldring 6
7000 Stuttgart 80 (Vaihingen)
Federal Republic of Germany

# GLOSSARY

| Abbreviation | Definition |
|---|---|
| A/C | Aircraft |
| AEDC | Arnold Engineering Development Center |
| AFCS/FCS | Auto Flight Control System |
| AFWAL | Air Force Wright Air Laboratories |
| AOA | Angle of Attack |
| ARC | Ames Research Center |
| ASTF | Aeropropulsion System Test Facility |
| ASTM | American Society of Testing Materials |
| ATC | Air Traffic Control |
| ATTAS | Advanced Technologies Testing Aircraft System |
| AVTS | Advanced Visual Technology System |
| AZ | Arizona |
| BA | British Aerospace |
| B/W | Black and White |
| CA | California |
| CCTV | Closed Circuit Television |
| CCV | Control Configured Vehicle |
| CDTI | Cockpit Display of Traffic Information |
| CGI | Computer Generated Imagery |
| C/O | Check Out |
| COF | Construction of Facilities (Budget) |
| CRT | Cathode Ray Tube |
| DFVLR | Deutsche Forschungs-und Versuchsanstalt fur Luft-und Raumfahrt |
| DNW | Duits-Nederlandse Windtunnel/Deutsch Niederlandischer Windkanal |
| DoD | Department of Defense (USA) |
| DVM | Digital Volt Meter |
| FFT | Fast Fourier Transform |
| FHI | Fuji Heavy Industries |

| Abbreviation | Definition |
|---|---|
| FOV | Field of View |
| FY | Fiscal Year |
| GA | General Aviation, Georgia |
| HUD | Heads Up Display |
| IHADSS | Integrated Helmet and Display Sight System |
| IN | Indiana |
| INS | Inertial Navigation System |
| IOS | Instrument Operating System |
| KHI | Kawasaki Heavy Industries |
| L/D | Lift Over Drag |
| LV | Laser Velocimeter |
| LaRC/LRC | Langley Research Center |
| LeRC | Lewis Research Center |
| MA | Modane, France |
| MIT | Massachusetts Institute of Technology |
| MO | Missouri |
| Mod | Modifications |
| MMU | Manned Maneuvering Unit |
| NAAL | North American Aeronautics Laboratory |
| NAL | National Aerospace Laboratory |
| NAPC | Naval Air Propulsion Center |
| NASA | National Aeronautics and Space Administration |
| NGTE | National Gas Turbine Engine Laboratory (Pyestock, UK) |
| NOE | Nap of the Earth |
| NRC | National Research Council |
| OH | Ohio |
| ONERA | Office National D'Etudes et de Recherches Aerospatiales |
| PA | Pennsylvania |
| RAE | Royal Aircraft Establishment |
| $R_e$ | Reynolds Number |
| Rehab | Rehabilitations |
| SCAS | Stability and Control Augmentation System |

| Abbreviation | Definition |
|---|---|
| TN | Tennessee |
| V/STOL | Vertical/Short Take Off and Landing Aircraft |
| VA | Virginia |
| WAL | Wright Aeronautical Laboratories |

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NASA RP-1133

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

Aeronautical Facilities Catalogue, Volume 2

5. Report Date
December 1985

6. Performing Organization Code
Code RF

7. Author(s)

Frank E. Peñaranda and M. Shannon Freda

8. Performing Organization Report No.

9. Performing Organization Name and Address

Office of Aeronautics and Space Technology
National Aeronautics and Space Administration
Washington, D. C. 20546

10. Work Unit No.

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

National Aeronautics and Space Administration
Washington, D. C. 20546

13. Type of Report and Period Covered
Reference Publication

14. Sponsoring Agency Code

15. Supplementary Notes

Second of two volumes. Volume 1 (NASA RP-1132) contains Wind Tunnel Facilities

16. Abstract

This second volume of the facilities catalogue deals with Airbreathing Propulsion and Flight Simulation Facilities. This reference book presents data pertinent to managers and engineers. Each facility is described on a data sheet that shows the facility's technical parameters on a chart and more detailed information in narratives. Facilities judged comparable in testing capability are noted and grouped together. Several comprehensive cross-indexes and charts are included.

17. Key Words (Suggested by Author(s))

Airbreathing Propulsion Facilities, Simulation Facilities, Engine Component Facilities, Free Jet, Turbine, Compressor, Combustor, Flight Decks

18. Distribution Statement

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